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THERMOPHYSICAL PROPERTIES OF SELECTED AEROSPACE MATERIALS

PART I: THERMAL RADIATIVE PROPERTIES

Y. S. TOULOUKIAN and C. Y. HO, Editors

THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION CENTER
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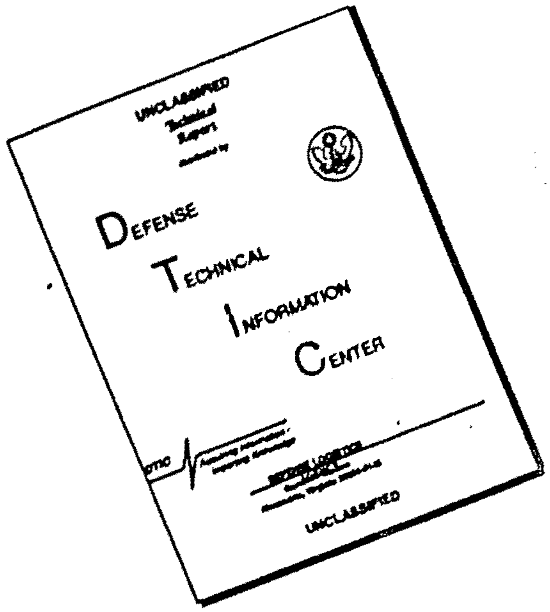

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(continued on reverse side)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This volume presents the most comprehensively compiled experimental data and the critically evaluated and recommended values for the thermal radiative properties (hemispherical, normal, angular) spectral emittance, reflectance, absorptance, and transmittance of twenty-seven selected aircraft/spacecraft structural materials of technological interest.

(continued on reverse side)

magnesium fluoride--pyroceram--silica--silicon--silicon carbide--silicon nitride--acrylic resins--lucite--silicone resins--plastics--boron composites--graphite composites--glass composites--epoxy composites--aluminized grafoil

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20. ABSTRACT (Cont)

Each subproperty is treated with respect to both wavelength and temperature dependences whenever possible. In the compilation of experimental data, all available data covering from the photographic region of the spectrum up to 100 microns are included. The recommended values resulting from critical evaluation, analysis, and synthesis of the available data and information cover the wavelength range of present interest from visible region to the infrared, if possible. Furthermore, the recommended values as a function of temperature are given for four particularly useful wavelengths.

The experimental data and the recommended values for each dependence of each subproperty of each material are presented in both tabular and graphical forms, together with a discussion text and a specification table. The former reviews and discusses the available data and information, the theoretical guidelines and other factors on which the critical evaluation, analysis, and synthesis of data are based, and the considerations involved in arriving at the final assessment and recommendations, and the latter gives the information on the specimen characterization and measurement method and condition for each set of experimental data.

In order to enable the user to fully utilize and property interpret the data and information presented in this reference work and also to enhance the usefulness of the data themselves, the theoretical background of thermal radiative properties is given at the beginning of the volume. Since most of the selected materials are not well known, a concise description of each of the materials is given at the beginning of each of the subsections.

PREFACE

This volume was prepared by the Thermophysical and Electronic Properties Information Analysis Center (TEPIAC), a DOD Information Analysis Center operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS), Purdue University, West Lafayette, Indiana.

The overall program is aimed at providing data and information on all the important thermophysical properties of twenty-seven selected aerospace materials. This Part I contains data and information on thermal radiative properties only. Other parts are in preparation to cover other thermophysical properties.

Because of the extensive scope and highly specialized nature of the work, the staff who contributed to this volume were drawn not only from TEPIAC but also from other CINDAS programs. The following key personnel comprised the team responsible for the authorship (including data compilation, evaluation, and generation of recommended values) of the sections on the various selected materials: Mr. M. W. Johnson (Aluminum Alloy 2024), Dr. P. D. Desai (Aluminum Alloy 7075 and Titanium Alloy Ti-6Al-4V), Mr. T. Y. R. Lee (AISI 304 Stainless Steel), Dr. R. A. Matula (Aluminum oxide, boron nitride, calcium aluminum silicate, magnesium fluoride, Pyroceram, and vitreous silica), Mr. T. N. Havill (silicon), Dr. K. Y. Wu (silicon carbide), Dr. T. C. Chi (silicon nitride, acrylic resins, Lucite, polycarbonate plastics, and silicone resins), and Dr. H. H. Li (aluminized grafoil, boron fiber aluminum matrix composite, graphite fiber aluminum matrix composite, boron fiber epoxy composite, glass fiber epoxy composite, and graphite fiber epoxy composite). The Scientific Documentation Division of TEPIAC provided the in-depth search of the literature supplemental to its basic coverage.

We wish to take this opportunity to acknowledge the assistance provided by many of our friends both in governmental laboratories and in industry. In most cases this assistance has taken the form of providing reports or papers not readily available.

It is hoped that the present volume will prove useful to a large technical community as it provides a wealth of knowledge heretofore unknown or inaccessible to many. In particular, it is felt that the critical evaluation, analysis and reference data recommendation, whenever possible, constitute perhaps the most unique aspect of this work.

In putting a volume of this magnitude together it is nearly impossible to avoid some errors and omissions. It is hoped that we were able to keep these to a minimum. The editors and contributors would be most grateful if those who use this volume bring to their attention any additional known data or any possible errors that might have been inadvertently committed.

Y. S. TOULOUKIAN
Director of CINDAS
Distinguished Atkins Professor of Engineering
Purdue University

May 1976
West Lafayette, IN 47906

SUMMARY

This volume presents the most comprehensively compiled experimental data and the critically evaluated and recommended values for the thermal radiative properties (hemispherical, normal, angular) spectral emittance, reflectance, absorptance, and transmittance of twenty-seven selected aircraft/spacecraft structural materials of technological interest.

Each subproperty is treated with respect to both wavelength and temperature dependences whenever possible. In the compilation of experimental data, all available data covering from the photographic region of the spectrum up to 100 μm are included. The recommended values resulting from critical evaluation, analysis, and synthesis of the available data and information cover the wavelength range of present interest from visible region (below 1 μm) to the infrared of 15 μm, if possible. Furthermore, the recommended values as a function of temperature are given for four particularly useful wavelengths (whenever possible): 2.8 μm, 3.8 μm, 5.0 μm, and 10.6 μm.

The experimental data and the recommended values for each dependence of each subproperty of each material are presented in both tabular and graphical forms, together with a discussion text and a specification table. The former reviews and discusses the available data and information, the theoretical guidelines and other factors on which the critical evaluation, analysis, and synthesis of data are based, and the considerations involved in arriving at the final assessment and recommendations, and the latter gives the information on the specimen characterization and measurement method and condition for each set of experimental data.

In order to enable the user to fully utilize and properly interpret the data and information presented in this reference work and also to enhance the usefulness of the data themselves, the theoretical background of thermal radiative properties is given at the beginning of the volume. Since most of the selected materials are not well known, a concise description of each of the materials is given at the beginning of each of the subsections.

The material and property coverage of this volume is summarized in the table entitled "Page Index to Materials and Properties" which appears on the next page.

PAGE INDEX TO MATERIALS AND PROPERTIES*

Material \ Property (Page No.)	Emittance						Reflectance						Absorptance						Transmittance					
	HSE (λ)	HSE (T)	NSE (λ)	NSE (T)	ASE (λ)	ASE (T)	HSR (λ)	HSR (T)	NSR (λ)	NSR (T)	ASR (λ)	ASR (T)	HSA (λ)	HSA (T)	NSA (λ)	NSA (T)	ASA (λ)	ASA (T)	HST (λ)	HST (T)	NST (λ)	NST (T)	AST (λ)	AST (T)
Aluminum Alloy 2024			28	38	41				46	61	64				94	102	108		113	113	113	113	113	113
Aluminum Alloy 7075			114		120				126		132				135		138		141	141	141	141	141	141
AISI 304 Stainless Steel			142	152					155	161	164				168	174			180	180	180	180	180	180
Titanium Alloy Ti-6Al-4V			181	188	192				195	201	205				211	217	221		224	224	224	224	224	224
Hadfield Manganese Steel																			225	225	225	225	225	225
Aluminum Oxide			226	247					253		260				265	269			270		274			
Boron Nitride			279	289					295		307										313			
Calcium Aluminum Silicate			320	329					332	342					345						349	357		
Magnesium Fluoride			363	376					379		387				391	399					402	415		
Pyroceram (Corning 9606)			419	423					427										433		437	446		
Silica (Vitreous)			447		468				477	488	491				500		509				512	527		
Silicon			532	551					558						567	570					573	587		
Silicon Carbide			593	606					613						626						633			
Silicon Nitride			647						654						661						667			
Acrylic Resins			684						690						699	705					707			
Lucite			728						731		737				743						749			
Polycarbonate Plastics			766						770		776				782						788			
Polyphenylquinoxaline																								
Silicone Resins			805						813		822										828			
Aluminized Grafoil			879	882					885	888					891	894			897	897	897	897	897	897
Boron Fiber/Aluminum			900	303					906	909					912	915			918	918	918	918	918	918
Graphite Fiber/Aluminum			921	924					927	930					933	936			939	939	939	939	939	939
Boron Fiber/Epoxy			941	944					947	953					956	959								
Glass Fiber/Epoxy			963	966					969	975					978	981								
Graphite Fiber/Epoxy			985	989					992	998					1001	1004								
Silicon Nitride/Graphite Fiber																			1007	1007	1007	1007	1007	1007
Silicon Nitride/Vitreous Silica																								

* In the column headings, H = Hemispherical, N = Normal, A (in the first position) = Angular, S = Spectral, E = Emittance, R = Reflectance, A (in the third position) = Absorptance, T = Transmittance, (λ) = Wavelength dependence, and (T) = Temperature dependence. Blank space indicates that no information is available.

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LIST OF SYMBOLS

a	Absorption coefficient
c	Velocity of light in vacuum
CLA	Center line average
d	Specimen thickness
E	Irradiance
I	Radiant intensity
j	Unit imaginary number
k	Absorption index
K*	Complex dielectric constant
L	Radiance
m	Electron mass; RMS slope
M	Exitance
n	Refractive index
n*	Complex refractive index
N	Number density of free electrons
P	A quantity in Fresnel equations
q	Electron charge
Q	Radiant energy; A quantity in Fresnel equations
r	Electrical resistivity
R	Single surface reflectance
RMS	Root mean square
t	Time
T	Internal transmittance; Temperature
V	Volume
W	Radiant density

α	Absorptance
α_p	Absorptance for incident radiation polarized parallel to plane of incidence
α_s	Absorptance for incident radiation polarized normal to plane of incidence
α_∞	Absorptivity
β	Temperature coefficient of electrical resistivity
ϵ	Emittance
ϵ_o	Permittivity of free space
ϵ_p	Emittance for radiation polarized parallel to plane of incidence
ϵ_s	Emittance for radiation polarized normal to plane of incidence
ϵ_∞	Emissivity
θ	Zenith angle for incident conditions
θ'	Zenith angle for viewing conditions
$\Delta\theta$	Half angle of acceptance of optical system
κ	Loss value factor
λ	Wavelength
ρ	Reflectance
ρ_p	Reflectance for incident radiant energy polarized parallel to plane of incidence
ρ_s	Reflectance for incident radiant energy polarized normal to plane of incidence
ρ_∞	Reflectivity
σ	RMS roughness
τ	Transmittance; Relaxation time
φ	Azimuthal angle for incident conditions
φ'	Azimuthal angle for viewing conditions
Φ	Radiant flux
Φ_a	Absorbed flux
Φ_i	Incident flux
Φ_r	Reflected flux

Φ_t	Transmitted flux
ω	Solid angle for incident conditions
ω'	Solid angle for viewing conditions

1. INTRODUCTION

This reference work presents the most comprehensively compiled experimental data and the critically evaluated and recommended values on the thermal radiative properties of twenty-seven selected aircraft/spacecraft structural materials.

The twenty-seven specific materials and generic groups of materials covered are the following:

	Melting Point (K)
1. Metals	
(1) Aluminum Alloy 2024	775-911
(2) Aluminum Alloy 7075	750-911
(3) AISI 304 Stainless Steel	1670-1727
(4) Titanium Alloy Ti-6Al-4V	1803-1908
(5) Hadfield Manganese Steel	1470-1480
2. Dome Materials	
(6) Aluminum oxide (Wesgo Al-300)	2315-2320
(7) Boron nitride	3273(sublimation)
(8) Calcium aluminum silicate (Corning 9753)	1723-1773
(9) Magnesium fluoride (Kodak IRTRAN 1)	1528
(10) Pyroceram (Corning 9606)	1623(softening)
(11) Silica (vitreous)	1950-2000
(12) Silicon	1687
(13) Silicon carbide	>2400(sublimation)
(14) Silicon nitride	2200(dissociation)
3. Transparent Materials	
(15) Acrylic resins	277-511(softening)
(16) Lucite	397(softening) 520(decomposition)
(17) Polycarbonate plastics	430(softening 580(decomposition)
(18) Polyphenylquinoxaline	780-830(decomposition)
(19) Silicone resins	473-873(thermal degradation)
4. Composites	
(20) Aluminized grafoil	933.52(M.P. of Al)
(21) Boron fiber aluminum matrix composite	933.52(M.P. of Al)
(22) Graphite fiber aluminum matrix composite	933.52(M.P. of Al)
(23) Boron fiber epoxy composite	590(epoxy decomposition)
(24) Glass fiber epoxy composite	590(epoxy decomposition)
(25) Graphite fiber epoxy composite	590(epoxy decomposition)
(26) Silicon nitride with chopped graphite fiber	
(27) Silicon nitride with vitreous silica	

The thermal radiative properties covered include the four prime properties: emittance, reflectance, absorptance, and transmittance. Additionally, each of the

prime properties are divided into three subproperties: hemispherical spectral, normal spectral, and angular spectral, and each subproperty is treated with respect to both wavelength and temperature dependences, wherever possible.

In the compilation of experimental data, all available data covering from the photographic region of the spectrum up to 100 μm are included. The recommended values resulting from critical evaluation, analysis, and synthesis of the available data and information cover the wavelength range of present interest from visible region (below 1 μm) to the infrared of 15 μm, if possible. Furthermore, the recommended values as a function of temperature are given for four particularly useful wavelengths (whenever possible); namely: 2.8, 3.8, 5.0, and 10.6 μm.

In order to enable the user to fully utilize and properly interpret the data and information presented in this report and also to enhance the usefulness of the data themselves, Section 2 provides the theoretical background of thermal radiative properties, which is believed useful. In Section 3 the procedure for data evaluation and the generation of recommended values is briefly outlined. The original experimental data and the critically evaluated and recommended values in both tabular and graphical forms for the various subproperties of the selected materials are given in Section 4, together with a discussion text and a table on measurement information. The discussion text reviews and discusses the available data and information, the theoretical guidelines and other factors on which the critical evaluation, analysis, and synthesis of data are based, and the considerations involved in arriving at the final assessment and recommendations. In this discussion text the accuracy or uncertainty of the recommended values is also stated. The table on measurement information contains the information on the specimen characterization and measurement method and condition for each set of experimental data. Since most of the selected materials are not well known, a concise description of each of the materials is given at the beginning of each of the subsections in Section 4. The complete bibliographic citations for the 332 references are given in Section 5.

2. THEORETICAL BACKGROUND*

2.1. General Remarks

The purpose of this section is to briefly explain the theoretical background that is helpful in understanding thermal radiative properties and the material presented in this report.

When light or other forms of electromagnetic radiation is incident on a material, three things can happen: the light is reflected, the light is absorbed, or the light is transmitted. Materials in general exhibit selective reflectance, absorptance, and transmittance, which means that the reflectance, absorptance, and transmittance vary with the wavelength of the incident light. For example, if the fraction of the incident light or radiative energy transmitted is plotted against wavelength, it would show peaks and valleys. What is the significance of peaks in a transmittance curve as a function of wavelength? When looking through a piece of blue glass which is illuminated by white light, it would appear blue to an observer. This means that the blue light with its characteristic wavelengths passes through the material and is not absorbed. Red glass which is illuminated by white light will appear red to an observer meaning that the red light with its characteristic wavelengths is not absorbed and passes through the glass with little loss in intensity. Thus, as a generalization, it can be stated that the wavelengths of light that are transmitted by a material are those wavelengths at which the light is not selectively absorbed by the material. This generalization holds not only for visible light but also for thermal radiation. The peaks or high values of transmittance correspond to the thermal radiation which is not absorbed at those particular wavelengths and the valleys or low values of transmittance correspond to the thermal radiation which is absorbed at those particular wavelengths. What physically occurs when light or thermal radiation at certain wavelengths is absorbed? A material is made up of a large number of atoms and/or molecules. These atoms or molecules can undergo various kinds of motion or changes in condition by excitation with light or other electromagnetic radiation of certain wavelengths. When the wavelength of the incident radiation is the same as the wavelength necessary to excite various kinds of motion or changes in condition, the atoms or molecules absorb the radiation of those wavelengths and the remaining radiation with other wavelengths is transmitted through the material.

Radiation is one of the three fundamental means of heat transfer, the others being conduction and convection. Radiation differs from the other means in two important respects: first, no medium is required for the transport of energy by radiation, and second,

* For details, see the text in [T61238 and T66579].

the rate of heat dissipation by radiation varies approximately as the fourth power of the absolute temperature, while that by the other means varies approximately as the first power of temperature. For these reasons, radiation becomes the dominant means of heat transfer at high temperatures and in the absence of an atmosphere.

The thermal radiative properties - emittance, reflectance, absorptance, and transmittance - are the parameters which are descriptive of the energy transported by means of radiation. The properties can be prescribed in greater detail to account for the spectral or wavelength conditions and the geometrical or directional conditions in which the radiant energy interacts with the solid. This interaction can be phenomenologically described by other properties as well, such as the optical constants, complex dielectric constant, or propagation factor, each of which is especially convenient for studying various aspects of the interaction.

There is a marked contrast between the radiative properties of metallic and nonmetallic solids. The magnitude of the radiative properties of the metallic solid is determined to a large extent by the surface condition; due to the high absorption index radiant energy will not travel more than a few hundred angstroms into the metal before being totally absorbed. As a result, surface roughness, oxide layer formations, structural defects due to mechanical stresses, etc. can be predominating influences on the property variations. The nonmetallic or dielectric materials are known to be less sensitive to surface conditions; the absorption and emission processes are "bulk" or "volume" phenomena. This is a consequence of appreciable transparency of the nonmetallic solid to thermal radiation.

The understanding of the basic mechanism of interaction between radiant energy and metallic solids is reasonably well developed. The behavior of the metallic solid is fairly adequately described by the free electron models which indeed are only approximate, but do provide simple and useful tools. The more sophisticated theories, while still not useful as yet for the prediction of numerical values from structural parameters, do provide a means for evaluation of experimental data and a basis for developing empirical relations to meet specific conditions. Our understanding of the theory of nonmetallic behavior is less well developed. The simplest model ascribes the nonmetallic behavior as due to a combination of several types of free electrons and electrons bound to the lattice. The theory is useful for basic understanding of behavior but not tractable for direct computation of property values. The problem is further complicated by transparency, scattering phenomena, and temperature gradients within the solid, which can usually be treated only in a gross or oversimplified manner.

In summary, then, pertaining to the principal differences between the metallic and nonmetallic behaviors, it can be stated that there are two: (1) the contributions of the transparency of nonmetallic solids giving rise to "volume" effects rather than "surface" effects which predominate the behavior of metallic solids, and (2) the lack of theoretical tools and simplified models for nonmetallic solids as are available for metallic materials.

2.2. Terminology

In order to understand the many terms and the notation used to describe thermal radiation, an explanation of relevant processes, things, quantities, properties, and descriptors, etc. is called for.

a. Processes

Radiation. The process by which radiant energy is emitted by a body. This process is also called emission.

Reflection. The process by which radiant energy incident on a surface or medium leaves that surface or medium from the incident side.

Transmission. The process by which radiant energy incident on a surface or medium leaves that surface or medium on a side other than the incident side.

Absorption. The process by which radiant energy is converted into another form of energy.

Propagation. The process or processes by which radiant energy is transferred from one region to another region in space.

b. Things

Radiator. A source of radiant energy.

Thermal Radiator. A radiator that emits thermal radiant energy, as a consequence of its temperature only.

Blackbody. A body or surface that absorbs all of the radiant energy incident upon it, and emits the maximum possible amount of thermal radiant energy at each frequency for a body at its temperature.

Reflector. A body that reflects incident radiant energy.

Transmitter. A body that transmits incident radiant energy.

Transparent Body. A body that transmits radiant energy directly, without diffusion or scattering, and has a relatively high transmittance.

Translucent Body. A body that transmits radiant energy principally by diffuse transmission. Objects are not seen distinctly through such a body.

Absorber. A body that absorbs incident radiant energy.

c. Quantities

Radiant Energy, Q. Energy in the form of electromagnetic waves or photons. Joules, ergs, or kilowatt-hours.

Thermal Radiant Energy, Q. Radiant energy that is emitted by a thermal radiator.

Radiant Density, W. $W = dQ/dV$. Radiant energy per unit volume. Joule per cubic meter, erg per cubic centimeter.

Radiant Flux, Φ. $\Phi = dQ/dt$. Time rate of flow of radiant energy. Erg per second, watt.

Radiant Intensity, I. $I = d\Phi/d\omega$. Flux per unit solid angle from a source. Watt per steradian.

Radiance, L. $L = d^2\Phi/d\omega\, dA \cos\theta$. Flux propagated in a given direction, per unit solid angle about that direction and per unit area projected normal to the direction.

Exitance, M. $M = d\Phi/dA$. Flux per unit area leaving a surface.

Irradiance, E. $E = d\Phi/dA$. Flux per unit area incident on a surface.

d. Properties

Properties ending in "ance" are properties of real specimens, regardless of thickness or surface condition. Properties ending in "ivity" are intrinsic properties of the material of which the specimen is composed, and can only be approached by values measured on real specimens that have clean optically smooth surfaces and are opaque.

Reflectance, ρ. The ratio of reflected flux to incident flux.

Absorptance, α. The ratio of absorbed flux to incident flux.

Transmittance, τ. The ratio of transmitted flux to incident flux.

Internal Transmittance, T. The ratio of the radiant flux reaching the exit surface to the flux which leaves the entry surface of a transparent body.

Emittance, ϵ. The ratio of the radiant exitance of a body at a given temperature to that of a blackbody radiator at the same temperature.

Reflectivity, ρ, ρ_∞. The reflectance of a specimen that has an optically smooth surface and is thick enough to be opaque.

Absorptivity, α, α_∞. The absorptance of a specimen that has an optically smooth surface and is thick enough to be opaque.

Emissivity, ϵ, ϵ_∞. The emittance of a specimen that has an optically smooth surface and is thick enough to be opaque.

Reflectance Factor, R. The ratio of the flux reflected by a specimen under specified conditions of irradiation and viewing to that reflected by the ideal completely reflecting, perfectly diffusing surface, identically irradiated and viewed.

For each of the four thermal radiative properties it is necessary to specify the wavelength conditions and the geometrical conditions applicable to the property.

e. Wavelength Descriptor

The only wavelength descriptor that is applicable to this report is the term "spectral". Used as a modifier for a thermal radiative property it means as a function of wavelength. For example, spectral transmittance means transmittance as a function of wavelength and is designated as $\tau(\lambda)$. Used in the context of a condition, the concept spectral means for a very narrow band of wavelength and is also referred to as monochromatic.

f. General Geometrical Descriptors

Figure 1 shows the general case of reflection at a surface and indicates the necessary geometric parameters required to fully describe the incident and reflected fluxes. The beams representing the incident and viewed flux are described by the zenith angles for θ and θ' and by the beam solid angles ω and ω'. The longitudinal angles Φ and Φ' relate the axes of the beams to each other and some reference line on the specimen; as a practical matter very few measurements so specify this angular descriptor. It is the convention in this report to distinguish three sets of general conditions as follows:

Normal - Conditions for incidence and/or viewing through a solid angle ω or ω', normal to the specimen; that is θ or $\theta' < 15°$.

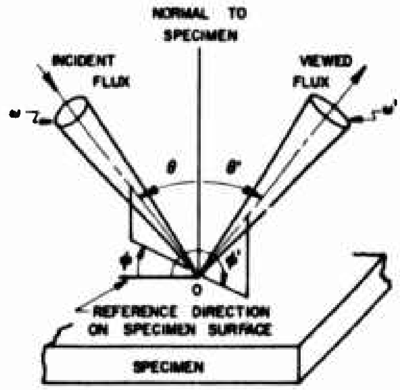


Figure 1. Geometric parameters descriptive of reflection from a surface. θ is the zenith angle, or colatitude, in degrees; Φ is the azimuthal angle, or longitude, in degrees; ω is the beam solid angle, in steradians; and the symbol ' refers to viewing conditions.

Angular - Conditions for incidence and/or viewing through a solid angle ω or ω' at some direction specified by θ or $\theta' \geq 15^\circ$

Hemispherical - Conditions for incidence and/or viewing of flux over a hemispherical region; that is ω or $\omega' = 2\pi$

The descriptors normal and angular do not fully describe the geometric conditions; ω and/or ω' and θ and θ' must be provided to fully specify the geometry.

g. Present Classification Scheme

In the classification scheme used in the data section of this report, reflectance, absorptance, and transmittance subproperties are grouped geometrically by incidence conditions and emittance is grouped by viewing conditions.

For absorptance, transmittance, and reflectance, hemispherical means the radiation is incident over a hemisphere, i.e., $\omega = 2\pi$, while normal means $\theta < 15^\circ$ and angular means $\theta \geq 15^\circ$. For emittance, hemispherical means $\omega' = 2\pi$, normal $\theta' < 15^\circ$, and angular $\theta' \geq 15^\circ$.

h. Symbolic Representation

The various subproperties are expressed according to the following convention. The symbols for the four primary properties ϵ, ρ, α, and τ have already been presented.

The geometric (incidence and viewing conditions) and wavelength descriptors, in that same order, are symbolically represented within the parentheses being separated by semicolons. The most general case would be (using reflectance as an example):

$$\rho(\theta, \Phi, \omega; \theta', \Phi', \omega'; \lambda)$$

where the wavelength descriptor, λ, used in this report has previously been defined.

As a practical matter not all the designations are always needed and many are omitted for convenience sake; usually Φ and Φ' are not used and, of course, for emittance and absorptance, the incidence and viewing geometry symbols, respectively, are not applicable.

It should be noted that for the subproperties of emittance and absorptance, only one geometric descriptor is required to designate the conditions of viewing and incidence, respectively. For the subproperties of reflectance and transmittance, two geometric descriptors are required since both incidence and viewing conditions need to be specified.

2.3. Interrelations Between Thermal Radiative Properties

All matter is continually emitting radiant energy as a result of the thermal vibration of the particles (electrons, ions, atoms, and molecules) of which it is composed. This process is called thermal radiation, and the radiant energy so emitted is called thermal radiant energy.

Each solid body is not only continually emitting thermal radiant energy, but it is also continually being bombarded by radiant energy from its surroundings, some of which is absorbed. The net rate of heat transfer by radiation to or from the body is equal to the difference in the rates of emission and absorption. Hence, the properties of the body that influence these rates are called thermal radiative properties.

When a body is irradiated, part of the incident radiant energy is reflected, part is absorbed, and the rest is transmitted. Nothing else can happen to it. The incident flux, Φ_i, is equal to the sum of the reflected flux, Φ_r, the absorbed flux, Φ_a, and the transmitted flux, Φ_t:

$$\Phi_i = \Phi_r + \Phi_a + \Phi_t \qquad (2.3\text{-}1)$$

This is an example of the Law of Conservation of Energy.

The reflectance, ρ, is the ratio of reflected flux to incident flux; the absorptance, α, is the ratio of absorbed flux to incident flux; and the transmittance, τ, is the ratio of transmitted flux to incident flux. Dividing both sides of eq. (2.3-1) by Φ_i gives

$$1 = \rho + \alpha + \tau \tag{2.3-2}$$

For opaque materials, $\tau = 0$, hence for such materials

$$\rho + \alpha = 1 \qquad (\tau = 0) \tag{2.3-3}$$

Kirchhoff's law states that the absorptance is equal to the emittance

$$\alpha = \epsilon \tag{2.3-4}$$

Thus, for an opaque material

$$\rho + \epsilon = 1 \tag{2.3-5}$$

and the thermal radiative properties of an opaque body are fully described by either the reflectance or the emittance. However, there are certain restrictions that apply to eqs. (2.3-2) through (2.3-5). They are restricted by the geometric and wavelength distribution of the reflected and emitted radiant energy. Considering the geometric distribution only, for opaque specimens

$$\alpha(\theta,\ \omega) = 1 - \rho(\theta,\ \omega;\ 2\pi) \tag{2.3-6}$$

where θ, ω are the same for α and ρ, and

$$\epsilon(\theta',\ \omega') = \alpha(\theta,\ \omega) \tag{2.3-7}$$

where $\theta = \theta'$ and $\omega = \omega'$. Equation (2.3-6) was derived on the basis of conservation of energy. Incident radiant energy that is not reflected must be absorbed and eq. (2.3-7) is a statement of Kirchhoff's law. Equations (2.3-6) and (2.3-7) can be used to convert one type of data (subproperty) to another. If normal emittance data are not available, for instance, normal absorptance or normal hemispherical reflectance can be used to compute the desired values.

The variation of the thermal radiative properties with temperature, wavelength, and geometric conditions (including polarization) of irradiation and viewing poses certain restrictions on eqs. (2.3-2) through (2.3-5). For eqs. (2.3-2) and (2.3-3) to be valid, α, ρ, and τ must be evaluated under the same conditions, which means that the temperature of the specimen must be the same, and the spectral composition, direction, solid angle, and degree and direction of polarization of the incident radiant energy must be identical, and all of the reflected and transmitted radiant energy must be measured.

Kirchhoff's law, eq. (2.3-4), is derived for the condition that the specimen is irradiated in a blackbody cavity with walls at the same temperature as the specimen, which means that the specimen is uniformly irradiated over a hemisphere with unpolarized radiant energy having the spectral distribution of that of a blackbody radiator at

the temperature of the specimen. However, it can be proved that eq. (2.3-4) is also valid for the two conditions: (1) any solid angle less than a hemisphere if the direction and solid angle of the incident beam for the absorption evaluation is identical to the direction and solid angle (but opposite in sense) of the emitted beam for the emittance evaluation, and (2) for plane-polarized radiant energy with the plane of polarization at any given angle to the plane of measurement, provided that it is the same for the incident radiant energy for the absorption evaluation and the emitted radiant energy for the emittance evaluation. Even with these modifications, eq. (2.3-4) applies strictly only provided the spectral composition of the incident radiant energy for the absorptance is that of blackbody radiant energy at the temperature of the specimen. This would appear to impose a severe restriction on the general applicability of eq. (2.3-5). However, it can also be shown that eq. (2.3-4) applies to any small wavelength band, as well as to total blackbody radiant energy. The properties of reflectance, absorptance, and transmittance do not vary with the amount of incident radiant energy until very high flux densities are reached. Within the narrow wavelength band used in measuring spectral thermal radiative properties the spectral distribution of radiant energy from almost any thermal source is approximately the same as that from a blackbody radiator at the temperature of the specimen. Also, polarization effects are completely absent for normally incident radiant energy and are negligible at angles near the normal. Hence eqs. (2.3-4) and (2.3-5) can be considered valid for normal spectral properties and can be used to convert normal hemispherical reflectance to normal emittance with but little error.

2.4. Fresnel Equations for Specular Reflection

When an electromagnetic wave in vacuum is incident on the plane surface of an optically homogeneous specimen, interaction of the wave with the material of the specimen will occur. The electrical and magnetic properties of the specimen will be different from those of the vacuum, and as a result, there may be a change in the direction of propagation of the wave, its velocity, amplitude, wavelength, and phase, and it may be separated into two portions, one reflected and one transmitted. The transmitted portion will be partially or totally absorbed. The only property of the wave that never changes is its frequency.

Similar changes in the wave will occur whenever it is incident on an interface between two media of different properties. The changes can be computed from the properties of the material, or the differences in properties on the two sides of the interface, and from the direction of propagation of the wave relative to the interface and the direction of its plane of polarization relative to the plane containing the direction of incidence and the normal to the interface at the point of incidence.

The optical properties describe the interaction of an electromagnetic wave with matter in terms of phase and amplitude, while the thermal radiative properties describe the energy transfer during the interaction. It is obvious that the two types of properties, optical and thermal radiative, are related. In some cases the relationships are simple.

One situation in which the relation is not simple is that for the general case of a wave incident on an interface. By solving the Maxwell equations for the boundary conditions, the Fresnel relations for specular reflection can be derived. The specular reflectance at the interface (fraction of incident flux reflected in the direction of mirror reflectance) is given as [see pp. 17 and 18 of A00012]

$$\rho_s(\theta) = \frac{Q^2 + P^2 - 2Q\cos\theta + \cos^2\theta}{Q^2 + P^2 + 2Q\cos\theta + \cos^2\theta} \tag{2.4-1}$$

$$\rho_p(\theta) = \rho_s(\theta)\,\frac{Q^2 + P^2 - 2Q\sin\theta\tan\theta + \sin^2\theta\tan^2\theta}{Q^2 + P^2 + 2Q\sin\theta\tan\theta + \sin^2\theta\tan^2\theta} \tag{2.4-2}$$

where

$$2Q^2 = [(n^2 - k^2 - \sin^2\theta)^2 + 4n^2k^2]^{1/2} + (n^2 - k^2 - \sin^2\theta) \tag{2.4-3}$$

$$2P^2 = [(n^2 - k^2 - \sin^2\theta)^2 + 4n^2k^2]^{1/2} - (n^2 - k^2 - \sin^2\theta) \tag{2.4-4}$$

The angle θ is the angle between the incident ray and the normal to the interface, ρ_s is the reflectance for plane-polarized incident radiant energy with its plane of polarization normal to the plane of incidence (the plane containing the incident ray and the normal to the interface at the point of incidence), ρ_p is the reflectance for plane-polarized incident radiant energy with its plane of polarization parallel to the plane of incidence, n is the refractive index, and k is the absorption index.

If the incident radiant energy is completely unpolarized

$$\rho(\theta) = \frac{1}{2}[\rho_s(\theta) + \rho_p(\theta)]. \tag{2.4-5}$$

For an opaque material the directional absorptance can be found and using Kirchhoff's law, eq. (2.3-4), the directional emittance can be found for the polarized components

$$\epsilon_s(\theta) = \alpha_s(\theta) = 1 - \rho_s(\theta) \tag{2.4-6}$$

$$\epsilon_p(\theta) = \alpha_p(\theta) = 1 - \rho_p(\theta) \tag{2.4-7}$$

and also for unpolarized light

$$\epsilon(\theta) = \alpha(\theta) = 1 - \rho(\theta) \tag{2.4-8}$$

The Fresnel eqs. (2.4-1) and (2.4-2) have been expressed in terms of n and k, but the relations are found in various forms in the literature. The simplest case occurs for normal incidence ($\theta = 0$), where the equations reduce to

$$\rho_p(0) = \rho_s(0) \tag{2.4-9}$$

and

$$Q = n \qquad P = k \tag{2.4-10}$$

Hence, for radiant energy incident from vacuum or a medium of index of refraction of 1,

$$\rho(0) = \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2} \tag{2.4-11}$$

2.5. Thermal Radiative Properties of Metals

a. General Behavior

The general behavior of the thermal radiative properties of metals is shown in Figure 2. For thicknesses greater than several hundred angstroms, metals are opaque, that is, they show zero transmittance for all wavelengths. The reflectance rises in the region of 1-2 μm to a large value which has a slightly increasing slope. The emittance and absorptance decrease rapidly in the region of 1-2 μm reaching a low value with a slight negative slope.

b. Classical Free-Electron Theory

The theoretical models for ideal metallic surfaces leads to help in predicting some thermal radiative properties.

The earliest attempts to predict the optical properties of metals were made by Lorentz, Drude [T20117], Kronig [A00023], and Mott and Zener [A00022], who assumed the metal to contain electrons which were essentially free to move under the influence of the electric field induced by the incident electromagnetic wave. These free electrons are the valence electrons in the outer shell of the atoms constituting the metal. When the wave is incident upon its surface, an oscillating electric field parallel to the surface is induced in the metal and the free electrons will oscillate under the influence of this field at the frequency of the incident wave. There is a phase difference between the

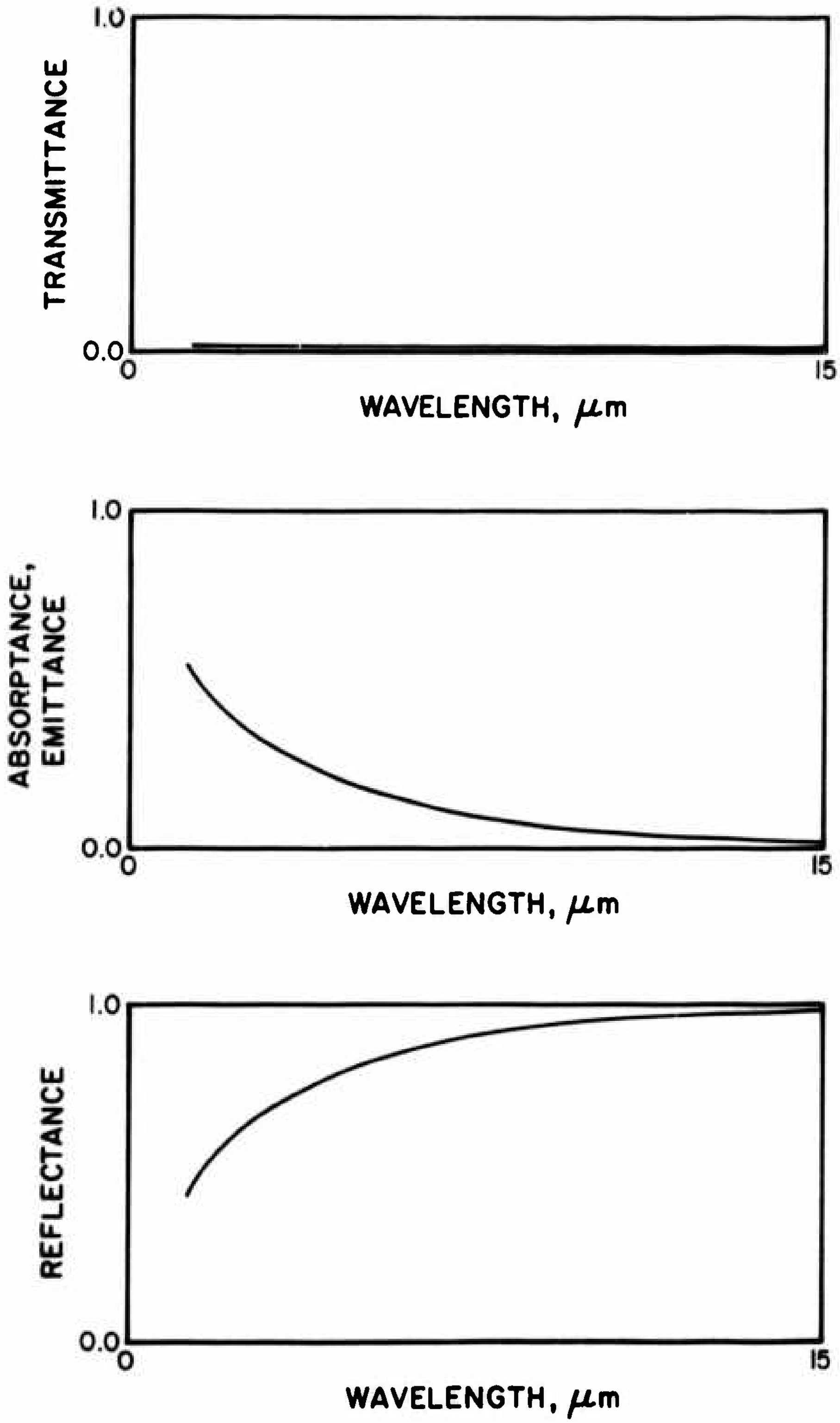


Figure 2. Typical behavior of thermal radiative properties of metals.

oscillation of the electrons and that of the field, caused by a viscous damping force arising from collisions between accelerated electrons and the atomic lattice. To describe the optical behavior of the material requires two parameters: the number density of free electrons, N, being excited by the induced field, and the average time (relaxation time, τ) between collisions of the electron with the atomic lattice. These two parameters can be estimated from the number of valence electrons per unit volume, the electrical conductivity and the assumption of a spherical Fermi surface. This is called the Drude Free Electron model, and is shown in Table 1 expressing the complex dielectric constant, K^*, as a function of the two parameters N and τ. See the List of Symbols for the meaning of other symbols.

If the phase change arising from electronic collisions can be neglected, the model describing the optical behavior of the material is greatly simplified. This situation occurs when the relaxation time is zero or when the time between electronic collisions is much less than the period of the induced electric field. For this condition, the optical behavior can be completely described by one material parameter - the dc electrical resistivity, r. Table 1 presents the resulting model for the complex dielectric constant, labeled the Simplified Drude Free Electron model.

This simplified model for the optical constants serves as the basis for relations used to compute the thermal radiative properties of materials from knowledge of the electrical resistivity (or conductivity) as a function of temperature. If the appropriate relation between the complex dielectric constant, K^*, and $\epsilon(0;\lambda)$ is used with the simplified Drude model, the normal spectral emissivity can be expressed as a function of the electrical resistivity, r, in the series form

$$\epsilon(0;\lambda) = 0.365(r/\lambda)^{1/2} - 0.0464(r/\lambda) + \ldots \tag{2.5-1}$$

Table 1. Classical Models for the Optical Properties of Metals (MKS Units)

Drude Free Electron. Assumes the metal contains free electrons which are subjected to an oscillating electric field and a viscous damping force proportional to the velocity of the electrons arising from collisions between accelerated electrons and the atomic lattice.	$K^* = 1 - \left(\frac{\lambda}{\lambda_0}\right)^2 \frac{1 + j(\lambda/\lambda_1)}{1 + (\lambda/\lambda_1)^2}$	$\lambda_1 = 2\pi c\tau$ $\lambda_0 = \left[\frac{\pi mc^2\epsilon_o}{q^2 N}\right]^{1/2}$
Simplified Drude Free Electron. Drude theory valid for long wavelengths where currents in the metal are in phase with electric field.	$K^* = -j\,\frac{\lambda}{c\epsilon_o r}$	

where the units are r(ohm-m) and λ(m). This celebrated relation is frequently referred to as the Hagen-Rubens relation.

From the above discussions, the assumptions used to derive this basic model limit the Hagen-Rubens relation to long wavelengths (usually beyond 10 μm) and high temperatures for metals in which the electronic structure can be approximated by one class of free electrons as the current carriers. This relationship has found extensive use in engineering applications.

An equation that can be used for the short wavelength region is developed by introducing a resonant wavelength into the denominator

$$\epsilon(0;\lambda) = A'\left(\frac{r}{\lambda - \lambda_0}\right)^{1/2} + B'\left(\frac{r}{\lambda - \lambda_0}\right) + \ldots \tag{2.5-2}$$

where A' and B' are adjustable parameters. For metals, the resistivity is connected with temperature as

$$r = r_0\,[1 + \beta\,(T - 293)] \tag{2.5-3}$$

where r_0 is the resistivity of the metal at 293 K and β is the temperature coefficient of the resistivity. Alternatively, the resistivity can be connected to the temperature by means of a power series

$$r = A' + B'\,T + C'\,T^2 + D'\,T^3 \tag{2.5-4}$$

Using eq. (2.5-3) in eq. (2.5-2), the Hagen-Rubens equation becomes

$$\epsilon(0,\lambda) = A + B\left[\frac{1+\beta(T-293)}{\lambda - \lambda_0}\right]^{1/2} + C\left[\frac{1+\beta(T-293)}{\lambda - \lambda_0}\right] + D\left[\frac{1+\beta(T-293)}{\lambda - \lambda_0}\right]^{3/2} \tag{2.5-5}$$

where A, B, C, D, and λ_0 are adjustable parameters. By finding the normal spectral emittance, the normal spectral absorptance and reflectance can be computed from Kirchhoff's law, i.e.,

$$\alpha(0,\lambda) = \epsilon(0,\lambda) \tag{2.5-6}$$

and then, since a metal is opaque, the reflectance can be found from

$$\rho(0,2\pi,\lambda) = 1 - \alpha(0,\lambda) \tag{2.5-7}$$

c. Non-Ideal Surfaces

The preceding discussion of the theoretical models used to predict radiative properties applied to ideal surfaces.

It has been understood for many years that the surface condition of metallic specimens plays a dominant role in the magnitude of the radiative properties. The literature abounds with examples of test surfaces shown to be very sensitive to methods of preparation, thermal history, and environmental conditions. Despite this awareness, descriptions of test surfaces are generally inadequate because of our modest understanding of the important mechanisms of real surface effects and how to properly characterize a surface.

Topographical, chemical, and physical (structural) characteristics all influence the properties of the metallic surface. The topographical characteristics describe the profile or geometry of the surface - the boundary between the material and the surrounding medium. The chemical characteristics describe the composition of the surface layer including such features as inhomogeneities and contaminants. The physical characteristics describe the structure of the surface such as crystal lattice orientation, particle size, strain, and other features which might affect the radiant energy exchange process.

To isolate the individual surface characteristics as outlined is a difficult task. For most materials it is not practical to alter one characteristic without causing an influence on another. The control of the many variables required to study surface characterization in a logical manner is a complex problem. As a result only the simplest of surface profiles or compositional effects have been studied or are understood.

The most important influences on the radiative properties of metals arise from surface roughness and films (oxide growth). The effect is most pronounced on the spectral radiative properties when the characteristic profile variation or film thickness is of the same order as the wavelength of interest. For some situations a thin dielectric film has a more significant influence on emittance properties than does surface roughness of the same dimension. These changes in spectral properties are also apparent as changes in angular distribution of reflected or emitted energy.

The influences of surface characteristics - topographical, chemical, physical - can be considerably dependent upon the energy spectrum of importance to the radiative property of interest. For example, the description of a surface for use as a room temperature absorber ($5 < \lambda < 40$ μm) will be quite different from that for a solar absorber ($0.25 < \lambda < 4$ μm). Also the techniques required to study each will be quite different.

The profiles of real metal surfaces are always shown as irregular patterns of peaks and valleys. Various parameters are in common use to describe the topography of a surface including RMS (root mean square) height, CLA (center line average) height,

lay, average slope, height distribution, etc. [A00021, T36500, A00020]. Such parameters are obtained primarily from stylus-type profilometers and to some extent from interferometry techniques.

The effect of surface roughness on the optical properties of materials was first studied by Lord Rayleigh, but only recently has this problem been of intense interest. If the size of the irregularities is of the order of the wavelength or larger, the interaction can be described by geometrical optics [T33896]. In this case, the facets of the surfaces reflect in various directions, and the properties/orientation of the facets must be described by some statistical process in order to explain the optical behavior of the surface. If, however, the surface irregularities are much smaller than the wavelength, the optical behavior can be explained by diffraction phenomena.

The diffraction problem was originally studied by Rice [A00019] and Davies [A00018] and their work was extended and experimentally verified by Bennett and Porteus [T45929]. Their expression for the relative reflectance ratio of the rough, ρ, to smooth, ρ_0, surface at normal incidence is given as

$$\frac{\rho}{\rho_0} = \exp\left[-(4\pi\sigma/\lambda)^2\right] + 32\pi^4 (\sigma/\lambda)^4 (\Delta\theta)^2/m \tag{2.5-6}$$

where σ is the RMS roughness, m is the RMS slope, and $\Delta\theta$ is the half angle of acceptance of the optical system. The first term represents the coherently or specularly reflected fraction and the second term the incoherent or diffusely reflected term. The second term is shown proportional to $(\sigma/\lambda)^4$, and hence for longer wavelengths and smoother surfaces the first term predominates.

2.6. Thermal Radiative Properties of Nonmetallic Solids

a. General Behavior

The typical behavior for a nonmetallic solid which is transparent with little scattering is shown in Figure 3. The transmittance rises sharply in the region of 1-2 μm to a large constant value and drops sharply towards zero in the 8-9 μm region (the use of the 1-2 μm range and the 8-9 μm range is done only for illustrative purposes). Since the reflectance is of the order of 10% and decreases slowly in the entire range of interest, the emittance and absorptance show a behavior as if the transmittance were rotated 180° about the wavelength axis. The emittance decreases sharply in the 1-2 μm region, stays at a constant but low level and in the 8-9 μm region rises sharply to a level near 1.0.

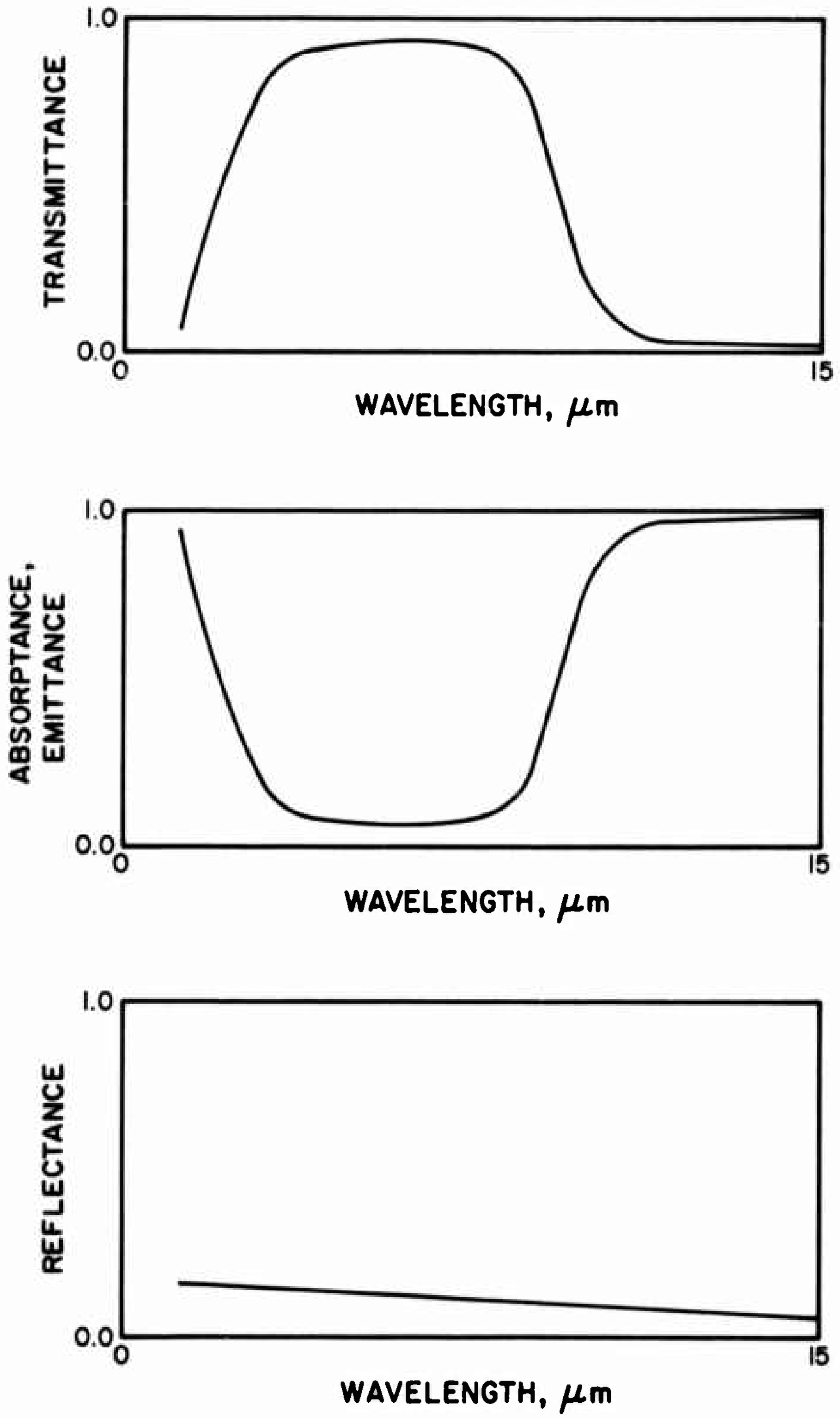


Figure 3. Typical behavior of thermal radiative properties of a transparent non-scattering nonmetallic solid.

b. Partially Transparent Material - Multiple Reflection Model

The simplest of the models to deal with the partially transparent nonscattering materials was developed by McMahon [T20468]. The theory is limited to only the passage of radiant energy normal to the surface but is useful to the very common problem of interpretation of reflectance or transmittance spectra of a partially reflecting slab sample.

Kirchhoff's law in its simplest form relates the spectral emissivity to spectral reflectivity of an opaque material as

$$\epsilon(\lambda, T) = 1 - \rho(\lambda, T) \tag{2.6-1}$$

For a body which is partially transparent because of its low absorption coefficient and/or thickness, Kirchhoff's law cannot be applied directly. Recall that the law derives from the existence of an energy balance between the emission and absorption of a body in thermal equilibrium within a uniformly heated enclosure. When the body is opaque, the incident flux is absorbed or reflected. If the body is partially transparent, the incident flux is absorbed and a significant fraction appears as reflected and transmitted flux after having undergone many internal reflections. For the general expression of Kirchhoff's law it is necessary to include the influence of transmittance.

McMahon shows the three measurable quantities emittance, reflectance, and transmittance are related to the single surface reflectance, R, and the internal transmittance, T, by the following expressions

$$\epsilon(\lambda) = \frac{[1-R(\lambda)]\,[1-T(\lambda)]}{[1-R(\lambda)\,T(\lambda)]} \tag{2.6-2}$$

$$\rho(\lambda) = R(\lambda)\left[1 + \frac{T^2(\lambda)\,[1-R(\lambda)]^2}{1-R^2(\lambda)\,T^2(\lambda)}\right] \tag{2.6-3}$$

$$\tau(\lambda) = T(\lambda)\,\frac{[1-R(\lambda)]^2}{[1-R^2(\lambda)\,T^2(\lambda)]} \tag{2.6-4}$$

The summation of these three equations is unity:

$$\epsilon(\lambda) + \rho(\lambda) + \tau(\lambda) = 1 \tag{2.6-5}$$

and this expression is the extension of Kirchhoff's law to partially transparent bodies.

Also, the results for ϵ, ρ, and τ can be understood by considering a collimated beam of radiant flux incident normally on a semitransparent slab of thickness d and complex index of refraction n^*. The incident flux upon first striking the interface is partially reflected and the balance passes through the interface. The reflected portion

R is computed from the Fresnel relations for normal incidence conditions

$$R = \left(\frac{n^* - 1}{n^* + 1}\right)^2 \tag{2.6-6}$$

It is important to recognize that this reflectance, R, is based upon a single reflection. The remaining flux that passes through the interface will traverse the thickness of the slab while being absorbed and eventually reach the back side. In the course of traversing the thickness of the slab, the radiant flux is diminished by a factor e^{-ad}, where a is the absorption coefficient and d is the specimen thickness. It is convenient to define the internal transmittance, T, as

$$T = e^{-ad} \tag{2.6-7}$$

which is the transmittance (frequently referred to as the transmissivity) within the material and is not affected by or inclusive of interface influences. Of the original flux striking the slab, the fraction $(1-R)T$ has reached the near side of the slab upon first traversing the slab thickness. At this near interface, a fraction R is reflected and the balance passes through. This process of multiple reflection at the interfaces and traversing of the thickness must be considered to determine the overall transmittance and reflectance of the slab. Figure 4 represents the multiple processes occurring, giving the results

$$\rho = R\left[1 + \frac{T^2(1 - R)^2}{1 - R^2T^2}\right] \tag{2.6-8}$$

$$\tau = T\left[\frac{(1 - R)^2}{1 - R^2T^2}\right] \tag{2.6-9}$$

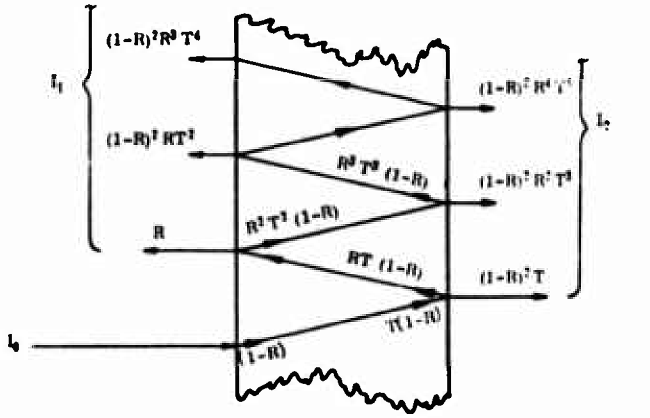
In terms of the single surface reflectance, R, absorption coefficient, a, and thickness, d, the relations are

$$\tau = \frac{(1 - R)^2 e^{-ad}}{1 - R^2 e^{-2ad}} \tag{2.6-10}$$

$$\rho = R\left[1 + \frac{e^{-2ad}(1 - R)^2}{1 - R^2 e^{-2ad}}\right] \tag{2.6-11}$$

$$\epsilon = \alpha = \frac{(1 - R)(1 - e^{-ad})}{1 - R e^{-ad}} \tag{2.6-12}$$

The above equations hold for $k \ll n$ where k is the absorption index ($\alpha = 4\pi k/\lambda$).



$$\rho = \frac{I_1}{I_0} = R + (1-R)^2RT^2 + (1-R)^2R^3T^4 + \ldots = R\left[1 + \frac{T^2(1-R)^2}{1-R^2T^2}\right]$$

$$\tau = \frac{I_2}{I_0} = (1-R)^2\left\{T + R^2T^3 + R^4T^5 + \ldots\right\} = T\,\frac{(1-R)^2}{1-R^2T^2}$$

Figure 4. The reflectivity and transmissivity of a semitransparent slab.

A special case of the eqs. (2.6-10) through (2.6-12) is for the case of zero absorption ($\alpha \to 0$). In that case

$$\epsilon = \alpha = 0 \qquad (2.6\text{-}13)$$

$$\tau = \frac{2n}{n^2 + 1} \qquad (2.6\text{-}14)$$

$$\rho = \frac{(n - 1)^2}{n^2 + 1} \qquad (2.6\text{-}15)$$

The extension of eq. (2.6-10) that holds for k not being less than n is [p. 14 of A00024]

$$\tau = \frac{(1 - R)^2\, e^{-ad}\left(1 + \frac{k^2}{n^2}\right)}{1 - R^2\, e^{-2ad}}$$

c. Kodak Scheme

Kodak has a method of calculating absorptance and reflectance from transmittance and refractive index data [E62600]. The energy impinging on a transparent slab is broken up into a reflected and transmitted beam. This is continued for three passes and the components added. The analysis is carried out in terms of the loss value factor, κ, from which reflectance and absorptance are calculated. The value of the loss value factor in terms of the measured transmittance, T, and the single surface reflectance, R, is

$$\kappa = \frac{1 - T - 2R\ (1 - R + R^2)}{1 - 2R + 4R^2} \tag{2.6-16}$$

and

$$\rho = R\,[1 + (1+\kappa)^2\ (1-R)^2] \tag{2.6-17}$$

$$\alpha = \epsilon = \kappa\ (1 - \kappa R) \tag{2.6-18}$$

d. Polymers

Pregelhof, Franey, and Haas [T77125] use a one-dimensional model for polycarbonate plastics, and assuming uniform properties, the emittance $\epsilon(\lambda)$, absorptance $\alpha(\lambda)$, transmittance $\tau(\lambda)$, and reflectance $\rho(\lambda)$ of a polymer sheet can be derived as follows.

$$\epsilon(\lambda) = \alpha(\lambda) = \frac{(1-R)\ [(1+R)\ \sinh ad + (1-R)\ (\cosh ad - 1)]}{(1+R^2)\ \sinh ad + (1-R^2)\ \cosh ad} \tag{2.6-19}$$

$$\tau(\lambda) = \frac{(1-R)^2}{(1+R^2)\ \sinh ad + (1-R^2)\ \cosh ad} \tag{2.6-20}$$

$$\rho(\lambda) = \frac{2R\ [R\ \sinh ad + (1-R)\ \cosh ad]}{(1+R^2)\ \sinh ad + (1-R^2)\ \cosh ad} \tag{2.6-21}$$

where $R = (n-1)^2/(n+1)^2$ and n is the refractive index, d is the thickness of the sample, and a is the absorption coefficient.

For the polycarbonate plastic bulk materials, it can be assumed that

$$e^{ad} \gg R^2 e^{-ad} \tag{2.6-22}$$

which enables eqs. (2.6-19) through (2.6-21) to become the following:

$$\epsilon(\lambda) = \alpha(\lambda) \cong (1-R)\ [1 - (1-R)\ e^{-ad} - Re^{-2ad}] \tag{2.6-23}$$

$$\tau(\lambda) \cong (1-R)^2\ e^{-ad} \tag{2.6-24}$$

$$\rho(\lambda) \cong R\ [1 + (1-2R)\ e^{-2ad}] \tag{2.6-25}$$

In a wavelength region when the material becomes opaque, i.e., $\tau = 0$, the absorptance can be obtained from

$$\alpha(\lambda) \cong (1-R)$$

3. DATA EVALUATION AND GENERATION OF RECOMMENDED VALUES

As a result of comprehensive search of literature, numerous research documents of interest to this program are uncovered. These documents are procured and studied, from which pertinent data are extracted, scrutinized, organized, key-punched, homogeneously tabulated, and plotted in huge working graphs readied for data analysis and synthesis. The information on specimen characterization and measurement methods and conditions is recorded in a table specially designed for recording measurement information, which includes (to the extent provided in the original source document) the following:

(1) Purity, chemical composition, dopant concentration, carrier concentration, defect concentration.

(2) Type of crystal, crystal axis orientation.

(3) Microstructure, grain size, inhomogeneity, additional phases.

(4) Specimen shape and dimensions.

(5) Method and procedure of fabrication.

(6) Manufacturer and supplier, stock number, catalog number.

(7) Heat, mechanical, irradiative, and other treatments.

(8) Surface conditions.

(9) Film thickness and substrate material.

(10) Test environment, degree of vacuum or pressure.

(11) Experimental method used in the measurement.

(12) Reference standard used in data observation or reduction.

(13) Form in which data are presented in the original source document other than tabular data.

(14) Other pertinent remarks.

Due to the difficulties in accurate measurement of thermal radiative properties of materials and in exact characterization of test specimens and surface conditions, the available experimental data extracted from various research documents are usually widely divergent and subject to large uncertainty. Data evaluation and analysis is therefore very important. The procedure involves critical evaluation of the validity and reliability of the data and related information, resolution and reconciliation of disagreements in conflicting data, correlation of data in terms of various controlling parameters, curve fitting with theoretical or empirical equations, comparison of results with theoretical predictions or with results derived from theoretical relationships or from generalized empirical correlations, etc. Besides critical evaluation and analysis of existing data,

theoretical methods and semiempirical techniques are employed to fill data gaps and to synthesize fragmentary data so that the resulting recommended values are internally consistent and cover as wide a range of wavelength or temperature as possible.

Depending upon the level of confidence the data analyst has placed on the values and upon the degree of completeness of characterization of the test material and surface conditions for which the values are generated, the values are designated as "recommended values", "provisional values", or "typical values". In this report, all the values generated have been properly designated, and the accuracy or uncertainty of the values clearly stated.

4. THERMAL RADIATIVE PROPERTIES OF SELECTED MATERIALS

In each of the following subsections the thermal radiative property data and information for each dependence of each subproperty of each material are presented in the following order: (1) discussion text, (2) table of recommended values, (3) figure of recommended curves, (4) figure of experimental data, (5) table of measurement information, and (6) table of experimental data.

In the discussion text, a review and discussion of the available data and information for the particular dependence of the particular subproperty of the material is given, together with a discussion of the theoretical guidelines and other factors on which the critical evaluation, analysis, and synthesis are based and of the considerations involved in arriving at the final assessment and recommendations.

In the table of recommended values, the values are tabulated with small increments in temperature or wavelength so that linear interpolation of values is meaningful. The recommended values cover the spectrum from visible region (below 1 μm) up to the infrared of 15 μm, whenever possible. Those values as a function of temperature are, whenever possible, tabulated for four particular gas-laser wavelengths: 2.8 μm (hydrogen fluoride laser), 3.8 μm (deuterium fluoride laser), 5.0 μm (carbon monoxide laser), and 10.6 μm (carbon dioxide laser). The values may be designated as recommended, provisional, or typical values. The accuracy or uncertainty of the values is stated in the discussion text. In this report, the ranges of uncertainties of recommended, provisional, and typical values are less than $\pm 15\%$, between $\pm 15\%$ and $\pm 30\%$, and greater than $\pm 30\%$, respectively.

In the figure of recommended curves, experimental data (sometimes selected) are also shown as background for comparison. The curves and data are plotted only up to 14 μm, even though the recommended values or available experimental data may exist above 14 μm. Those values or data above 14 μm not shown in the figure can always be found in the table.

In the figure of experimental data, similarly, data in the wavelength range above 14 μm are not shown. They are, however, tabulated in the experimental data table. Corresponding to each set of data plotted in the figure and tabulated in the experimental data table, the information on the specimen characterization and measurement method and condition is given in the table of measurement information.

Since most of the selected materials are not well known, a concise description of each of the materials is given at the beginning of each of the subsections.

4.1. Aluminum Alloy 2024

Aluminum Alloy 2024, formerly known as Aluminum Alloy 24S, is a wrought alloy with copper as the principal alloying element. Its nominal composition [A00005] is (by weight) 4.5% Cu, 1.5% Mg, 0.6% Mn, and balance Al.

Some physical [T15906] and mechanical properties [A00006] of this material are as follows: solidus temperature, 775 K; liquidus temperature, 911 K; specific gravity, 2.77; tensile (ultimate) strength, 19.0-51.0 kg/mm^2; Brinell hardness number (500 kg load, 10 mm ball), 47-130. These properties vary over a wide range due to differences in applied heat treatments.

In the heat treated condition, the mechanical properties of this alloy are similar to, and sometimes exceed, those of mild steel. This heat treatment is specified by a letter "T" after the 2024 designation. The "T", followed by the numerals 1-10, inclusive, designates one specific combination of basic treatments, thus Aluminum Alloy 2024-T4. Briefly, these heat treatments are broken down as follows [A00006]:

- T1 - cooled from an elevated temperature shaping process and naturally aged to a substantially stable condition.
- T2 - annealed (cast products only)
- T3 - solution heat-treated and then cold worked
- T4 - solution heat-treated and naturally aged to a substantially stable condition
- T5 - cooled from an elevated temperature shaping process and then artificially aged
- T6 - solution heat-treated and then artificially aged
- T7 - solution heat-treated and then stabilized
- T8 - solution heat-treated, cold worked, and then artificially aged
- T9 - solution heat-treated, artificially aged, and then cold worked
- T10 - cooled from an elevated temperature shaping process, artificially aged, and then cold worked.

Each of these thermal treatments [A00005] has a unique effect on the mechanical properties of the alloy. The symbol does not define the time and temperature of the thermal treatments; the details of the practice may be varied as desired or convenient if the end result as expressed by specified mechanical properties is unchanged. Should variation of the same basic operation be applied to the same alloy, resulting in different characteristics, other digits are added to the basic designation (Aluminum Alloy 2024-T81 or Aluminum Alloy 2024-T851). The second and third numbers in the heat treatment designation are arbitrary numbers, generally having no logical significance. With the

older nomenclature the specific heat treatments were not catalogued as above. An alloy may be described as Aluminum 24S-T, where the T only means that the material was tempered to a stable condition.

This alloy does not have as good corrosion resistance properties as most other aluminum alloys and under certain conditions may be subjected to intergrannular corrosion. Therefore, it is widely used in the clad, anodized, or alodined states. In the clad [A00006] state the 2024 Aluminum Alloy is protected from corrosion by a thin surface of pure metal or an alloy with a higher solution potential than Aluminum Alloy 2024. In this report the term alclad was assumed to have meant the cladding material was pure aluminum. The anodizing [A00005] process involves forming a conversion coating on the metal surface by anodic oxidation. Alodining is also a conversion coating, with the coating being some other type of material such as a phosphate or chromate. These processes greatly increase Aluminum Alloy 2024's resistance to corrosion.

In this report data is actually reported for four different types of Aluminum Alloy 2024 for different subproperties. These types are as follows: Aluminum Alloy 2024 (either heat-treated or not heat-treated), alclad Aluminum Alloy 2024, alodined Aluminum Alloy 2024, and anodized Aluminum Alloy 2024. The provisional values for alclad Aluminum Alloy 2024 are from theoretical calculations using the relation discussed in subsection 4.20, based on Eq. (2.5-5), to calculate normal spectral reflectance. The data given for this alodined Aluminum Alloy 2024 is for a chromate conversion coating applied to the specimen. So, likewise, the provisional curves for the alodined specimen are for this same chromate coating. For the anodized specimen, the surface is actually a layer of aluminum oxide. Therefore, the provisional curves are for this same type of specimen.

No data was located for the following subproperties of aluminum alloy 2024: HSE(T), NSE(T), ASE(λ), ASE(T), HSR(λ), HSR(T), NSR(T), ASR(T), HSA(λ), HSA(T), ASA(λ), and ASA(T).

Data in the data tables also includes data for grooved surfaces of Aluminum Alloy 2024 for the subproperties ASR(λ) and NSR(λ). These data points are not plotted but are included in the report.

Aluminum Alloy 2024 is perhaps the best known and most widely used aircraft alloy.

a. Normal Spectral Emittance (Wavelength Dependence)

There are seven sets of experimental data available for the wavelength dependence (0.12-27.0 μm) of the normal spectral emittance of Aluminum Alloy 2024 under various

surface conditions. These are listed in Table 1-3 and shown in Figures 1-2 and 1-5.

(1) Highly Polished Aluminum Alloy 2024

The recommended values listed in Table 1-1 and shown in Figure 1-1 for highly polished Aluminum Alloy 2024 were generated from the absorptance data reported by Schriempf and Wieting [A00003] and are believed to be accurate to ± 10% over the entire wavelength range at 293 K.

(2) Highly Polished Alclad Aluminum Alloy 2024

The recommended values listed in Table 1-1 and shown in Figure 1-3 for highly polished alclad Aluminum Alloy 2024 were generated with the relation discussed in subsection 4.20, based on Eq. (2.5-5), and are believed accurate to ± 10% at the reported wavelength range at 293 K. These values are consistent with the normal spectral reflectance data of Grimm and Fannin [A00001] on a similar material. Provisional values at 450, 600, and 750 K tabulated in Table 1-1 and shown in Figure 1-3 were calculated with the relation discussed in subsection 4.20, based on Eq. (2.5-5), and are believed accurate to ± 20% over the entire wavelength region for a highly polished (ideal) surface.

(3) Oxidized Aluminum Alloy 2024

Provisional values at 823 K listed in Table 1-1 and shown in Figure 1-4 were generated from the data of Blau, et al. [T16606] and are believed accurate to ± 20% over the entire wavelength range.

TABLE 1-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
HIGHLY POLISHED T = 293		HIGHLY POLISHED ALCLAD T = 293		HIGHLY POLISHED ALCLAD T = 450		HIGHLY POLISHED ALCLAD T = 600		HIGHLY FOLISHED ALCLAD T = 750		OXIDIZED ALLOY T = 823	
2.20	0.0980	2.5	0.067	2.5	0.071A†	2.5	0.073A†	2.5	0.075A†	2.0	0.426A†
2.80	0.0760	2.8	0.057	2.8	0.063A	2.8	0.067A	2.8	0.069A	2.2	0.418A
3.00	0.0697	3.0	0.052	3.0	0.059A	3.0	0.063A	3.0	0.066A	2.5	0.410A
3.50	0.0575	3.5	0.044	3.5	0.052A	3.5	0.056A	3.5	0.060A	2.8	0.403A
3.80	0.0524	3.8	0.041	3.8	0.048A	3.8	0.053A	3.8	0.057A	3.0	0.399A
4.00	0.0438	4.0	0.039	4.0	0.046A	4.0	0.051A	4.0	0.055A	3.2	0.394A
4.50	0.0440	4.5	0.035	4.5	0.043A	4.5	0.047A	4.5	0.051A	3.5	0.386A
5.00	0.0402	5.0	0.033	5.0	0.040A	5.0	0.044A	5.0	0.048A	3.8	0.381A
5.50	0.0375	5.5	0.031	5.5	0.037A	5.5	0.042A	5.5	0.046A	4.0	0.376A
6.00	0.0355	6.0	0.029	6.0	0.035A	6.0	0.040A	6.0	0.043A	4.2	0.374A
6.50	0.0338	6.5	0.027	6.5	0.034A	6.5	0.038A	6.5	0.042A	4.5	0.366A
7.00	0.0323	7.0	0.026	7.0	0.032A	7.0	0.037A	7.0	0.040A	4.8	0.362A
7 50	0.0310	7.5	0.025	7.5	0.031A	7.5	0.035A	7.5	0.039A	5.0	0.360A
8.00	0.0298	8.0	0.024	8.0	0.030A	8.0	0.034A	8.0	0.037A	5.2	0.356A
8.50	0.0287	8.5	0.023	8.5	0.029A	8.5	0.033A	8.5	0.036A	5.5	0.351A
9.00	0.0278	9.0	0.023	9.0	0.028A	9.0	0.032A	9.0	0.035A	5.8	0.346A
9.50	0.0272	9.5	0.022	9.5	0.027A	9.5	0.031A	9.5	0.034A	6.0	0.342A
10.00	0.0270	10.0	0.021	10.0	0.026A	10.0	0.030A	10.0	0.033A	6.2	0.340A
10.60	0.0262	10.5	0.021	10.5	0.026A	10.5	0.029A	10.5	0.032A	6.5	0.336A
11.00	0.0258	11.0	0.020	11.0	0.025A	11.0	0.029A	11.0	0.032A	7.0	0.330A
11.50	0.0254	11.5	0.020	11.5	0.025A	11.5	0.028A	11.5	0.031A	7.2	0.328A
12.00	0.0250	12.0	0.019	12.0	0.024A	12.0	0.028A	12.0	0.030A	7.5	0.323A
12.50	0.0246	12.5	0.019	12.5	0.024A	12.5	0.027A	12.5	0.030A	8.0	0.317A
13.00	0.0242	13.0	0.019	13.0	0.023A	13.0	0.026A	13.0	0.029A	8.5	0.310A
13.50	0.0239	13.5	0.018	13.5	0.023A	13.5	0.026A	13.5	0.029A	9.0	0.303A
14.00	0.0235	14.0	0.018	14.0	0.022A	14.0	0.025A	14.0	0.028A	9.5	0.296A
14.50	0.0232	14.5	0.017	14.5	0.022A	14.5	0.025A	14.5	0.028A	10.0	0.290A
15.00	0.0228	15.0	0.017	15.0	0.021A	15.0	0.025A	15.0	0.027A	10.5	0.284A
										11.0	0.277A
										11.5	0.271A
										12.0	0.266A
										12.5	0.261A
										13.0	0.256A
										13.5	0.252A
										14.0	0.248A

† VALUE FOLLOWED BY AN "A" IS PROVISIONAL.

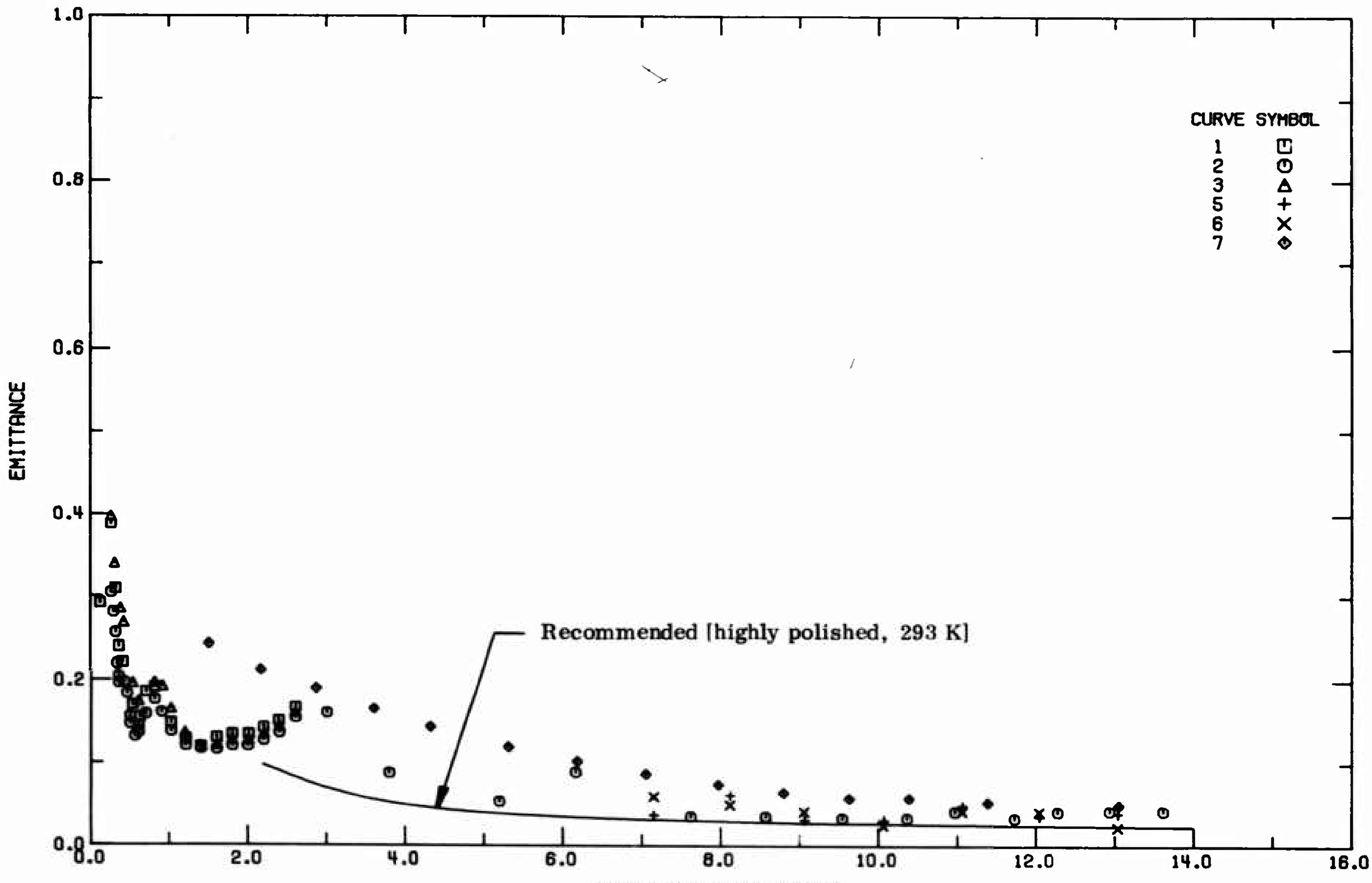


FIGURE 1-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

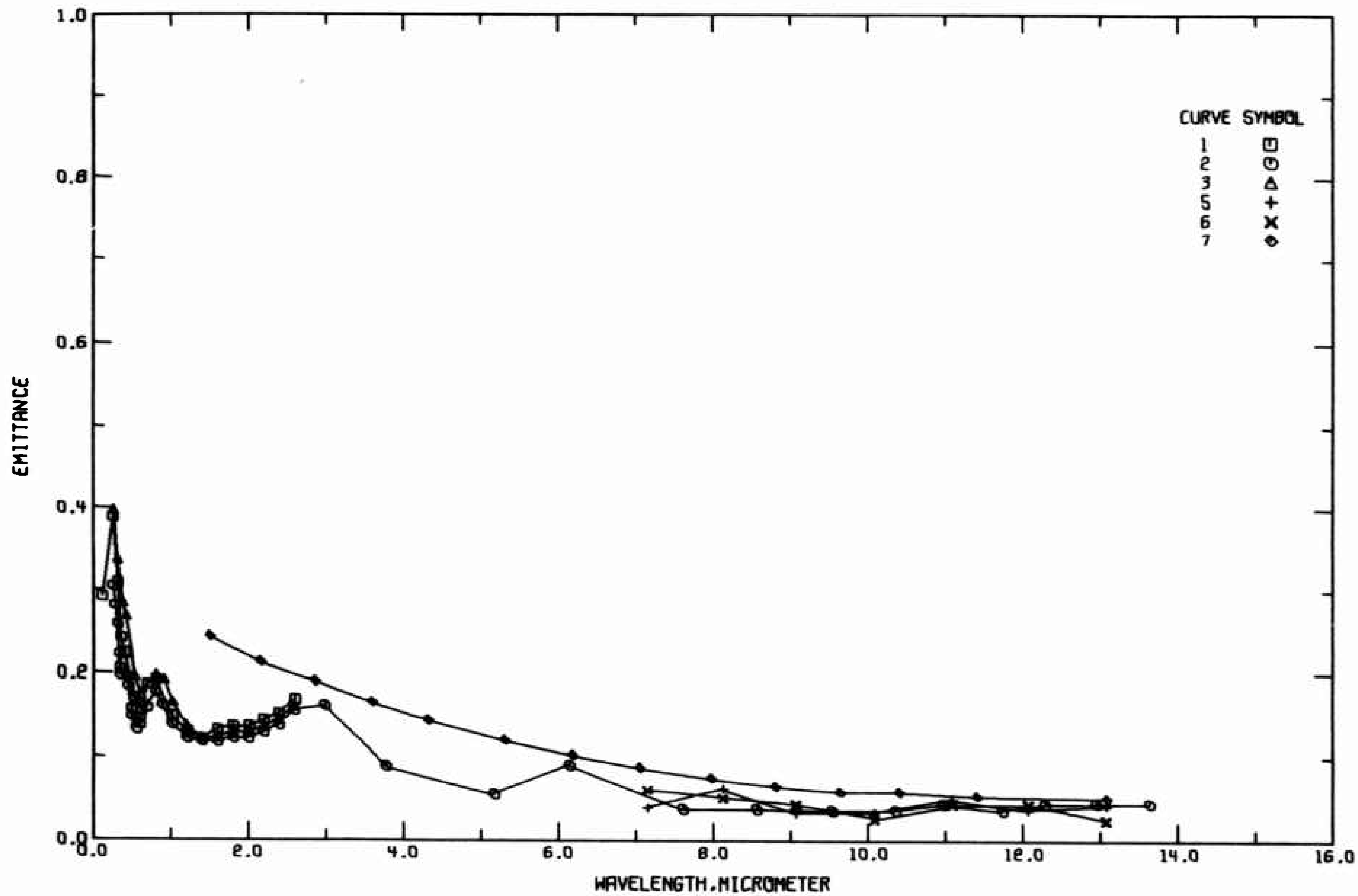


FIGURE 1-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

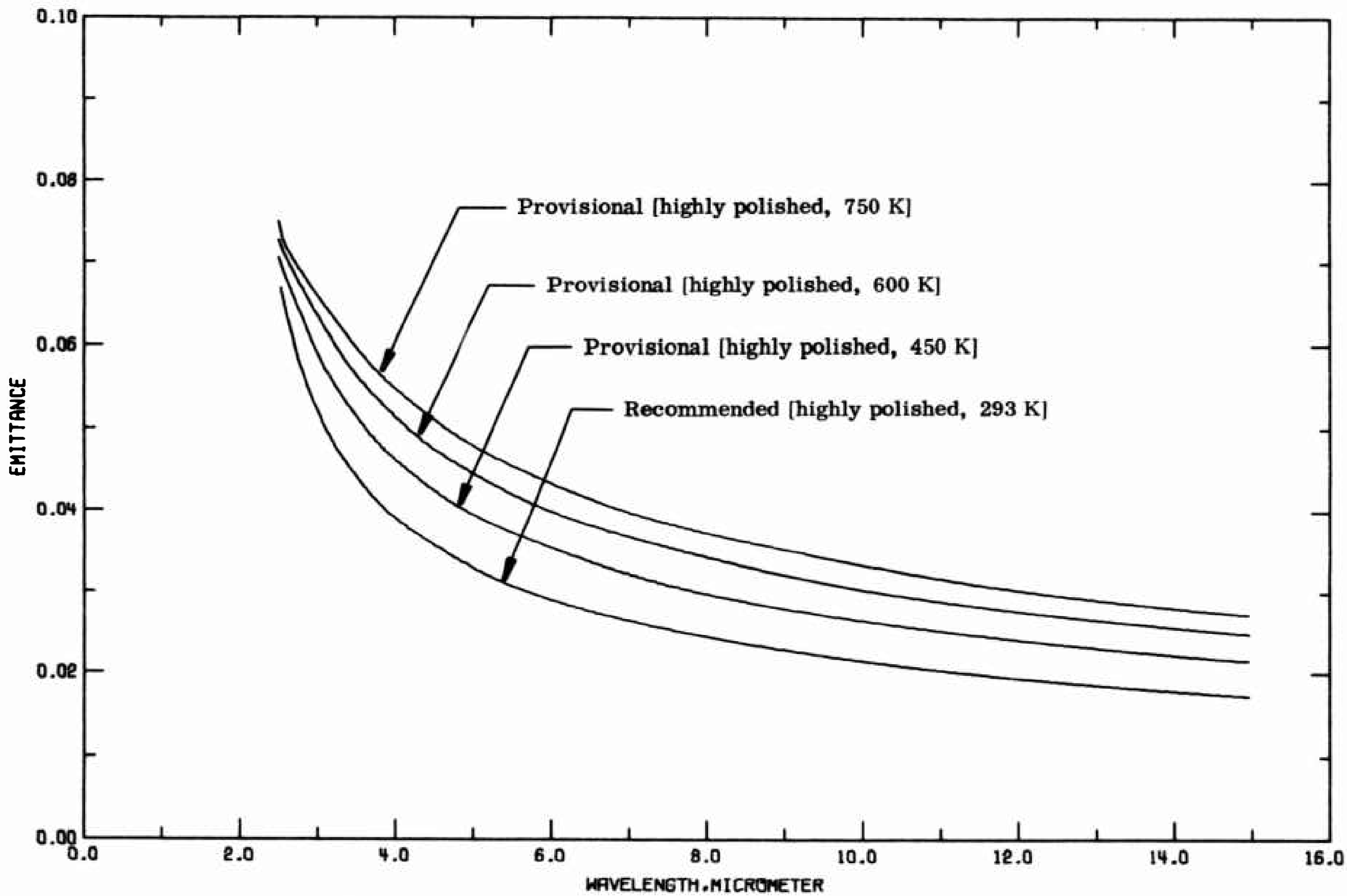


FIGURE 1-3. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF ALCLAD ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

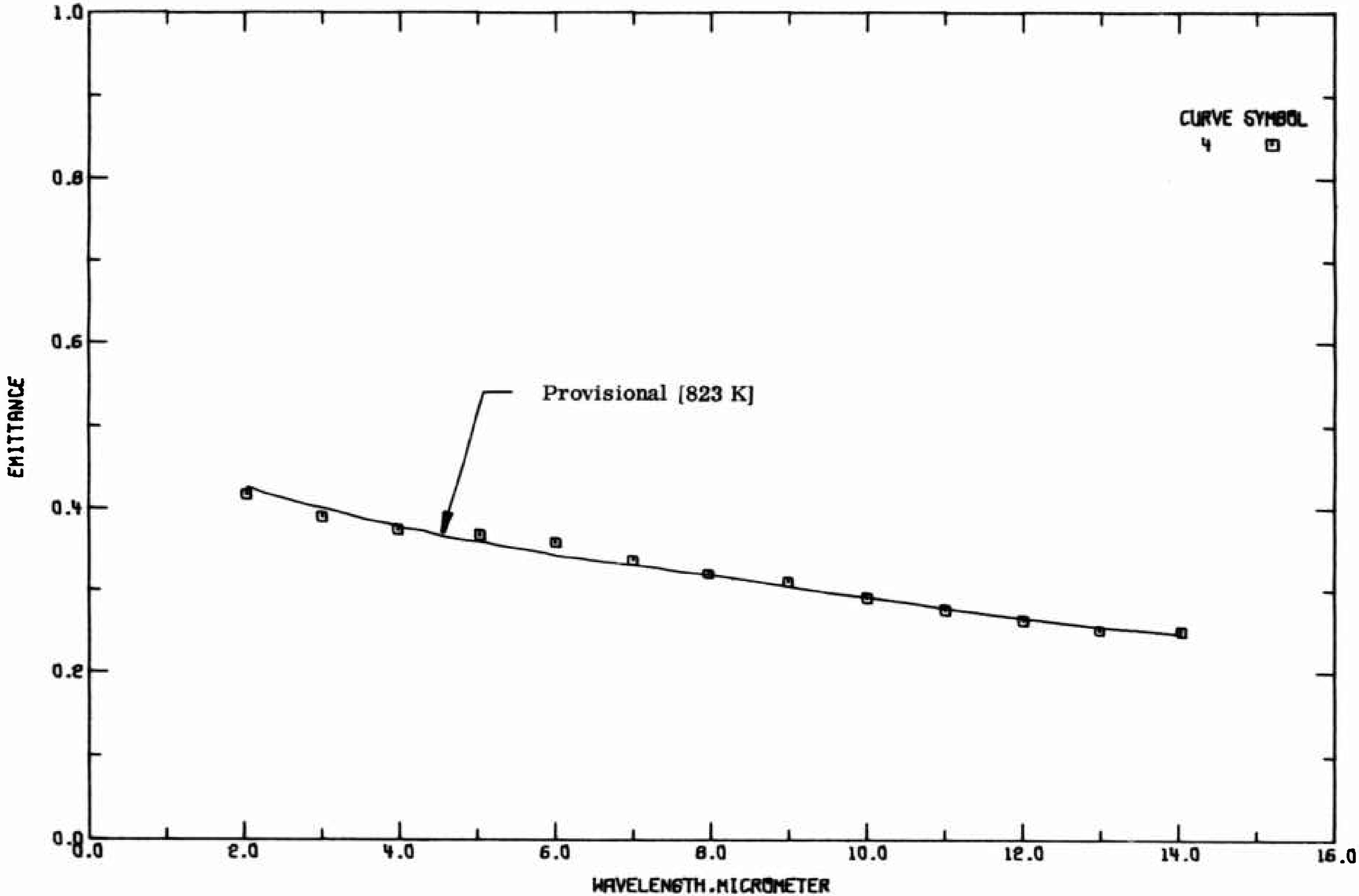


FIGURE 1-4. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF OXIDIZED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

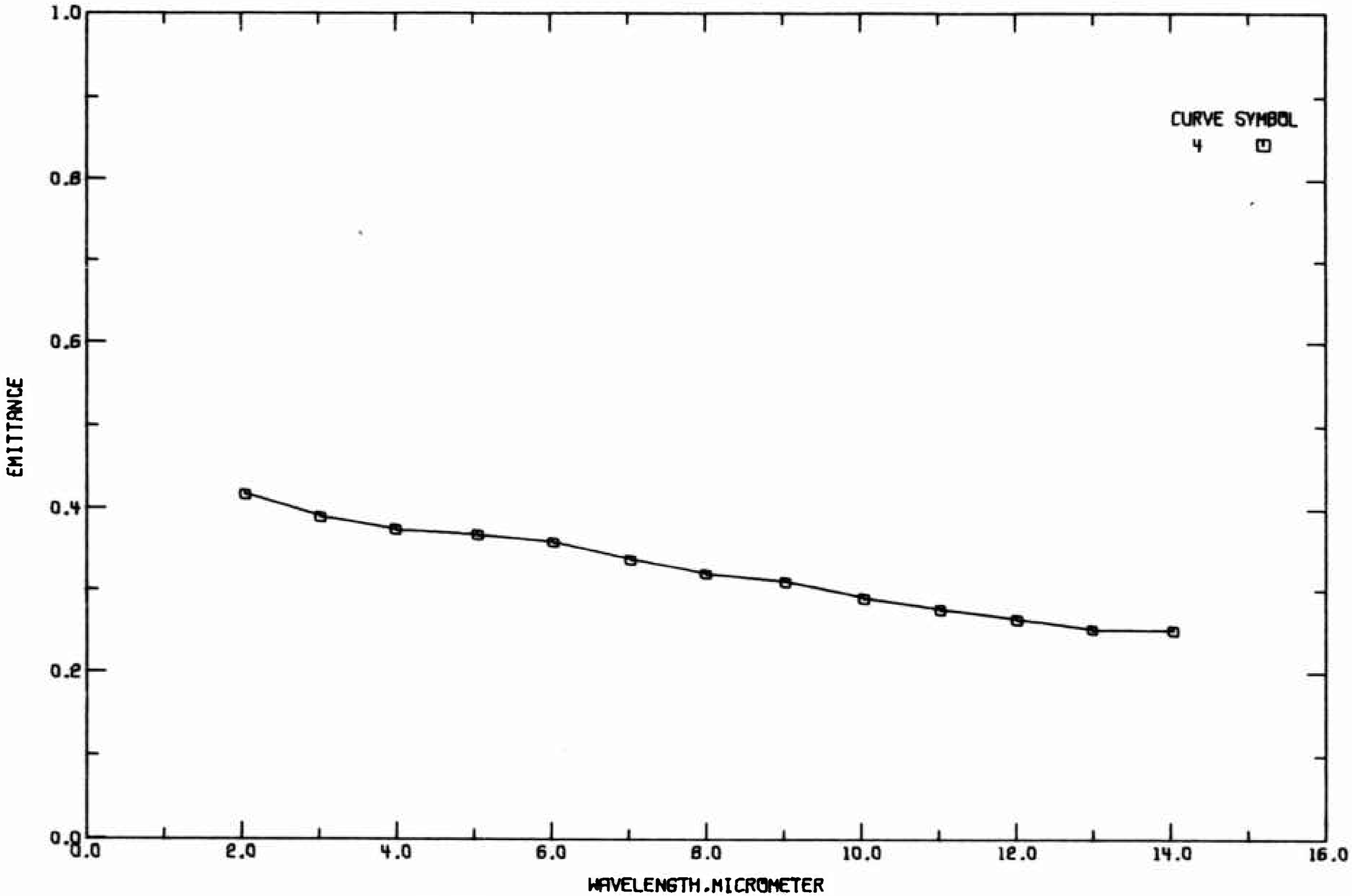


FIGURE 1-5. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

TABLE 1-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T29202	Research Projects Div., G.C. Marshall Space Flight Center	1963	0.12-2.6	323	Specimen 1	Front surface of sample was initially roughened with a variety of emery papers, sample then brought to a fine polish with grinding wheel and alumina powder; measurements made at equivalent time periods in temperature-humidity controlled room; measurements in 0.25-2.5 μm wavelength region were made with a Beckman 24500 reflectance unit and a Beckman DK-2 monochromator in conjunction with an integrating sphere; reported values of normal spectral emittance calculated from formula $\epsilon = 1 - r$; data extracted from figure.
2	T29202	Research Projects Div., G.C. Marshall Space Flight Center	1963	0.26-27.0	323	Specimen 3	Different sample, the above specimen and conditions; measurements in infrared region of spectrum made with an energy detector.
3	T29202	Research Projects Div., G.C. Marshall Space Flight Center	1963	0.26-2.6	323	Specimen 4	Different sample, the above specimen and conditions.
4	T16606	Blau, H.H., Chaffee, E., Marsh, J.B., Martin, W.J., and Jasperse, J.R.	1960	2.0-14.0	823		Unpolished, oxidized in air for 2 hr; specimen heated by silicon carbide furnace, emittance measured by Perkin-Elmer Model 12C energy detector; data extracted from figure; $\theta' \approx 0°$, reported error ±4%.
5	T20470	Weber, D.	1959	7.15-15.06	383	24ST Aluminum (ANA13-362)	Specimen reported as flat and smooth; Perkin-Elmer Model 112 infrared spectrometer used for measurements; normal emissivity assumed; data extracted from figure; reported error ± 50%.
6	T20470	Weber, D.	1959	7.15-15.06	303	24ST Aluminum (ANA13-362)	The above specimen and conditions.
7	T21553	Berry, J., Lee, T., and Shaw, C.	1959	1.5-21.0	301		Specimen buffed on wheel with jewelers rouge for 17 min; data extracted from smooth curve; normal emissivity assumed.

TABLE 1-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

CURVE 1
T = 323.

λ	ε
0.12	0.291
0.26	0.387
0.32	0.309
0.36	0.240
0.41	0.222
0.53	0.170
0.62	0.155
0.70	0.186
0.81	0.192
1.02	0.148
1.21	0.129
1.40	0.120
1.60	0.131
1.80	0.135
2.01	0.135
2.20	0.143
2.39	0.151
2.60	0.168

CURVE 2
T = 323.

λ	ε
0.26	0.304
0.29	0.280
0.32	0.256
0.34	0.220
0.35	0.205
0.35	0.197
0.42	0.198
0.46	0.184
0.50	0.156
0.50	0.147
0.56	0.132
0.61	0.137
0.61	0.145
0.70	0.159
0.81	0.177
0.90	0.161
1.02	0.138

CURVE 2 (CONT.)

λ	ε
1.21	0.121
1.40	0.118
1.60	0.117
1.80	0.121
2.00	0.121
2.20	0.128
2.40	0.137
2.60	0.155
3.00	0.161
3.79	0.089
5.19	0.054
6.16	0.090
7.62	0.036
8.57	0.036
9.54	0.034
10.36	0.034
10.97	0.042
11.73	0.034
12.28	0.042
12.94	0.043
13.62	0.043
14.04	0.057
14.08	0.052
14.12	0.042
14.65	0.060
16.27	0.051
16.27	0.044
18.27	0.039
20.10	0.038
21.78	0.047
24.32	0.064
26.98	0.060

CURVE 3
T = 323.

λ	ε
0.26	0.398
0.31	0.339
0.38	0.285
0.42	0.268

CURVE 3 (CONT.)

λ	ε
0.53	0.197
0.61	0.175
0.81	0.198
0.91	0.193
1.02	0.166
1.20	0.137
1.39	0.121
1.61	0.123
1.80	0.129
2.01	0.129
2.21	0.136
2.40	0.145
2.60	0.161

CURVE 4
T = 823.

λ	ε
2.03	0.417
3.00	0.390
3.97	0.375
5.02	0.369
5.99	0.360
6.98	0.338
7.95	0.320
8.97	0.310
9.98	0.291
10.98	0.277
11.98	0.265
12.95	0.253
14.00	0.252

CURVE 5
T = 383.

λ	ε
7.15	0.038
8.12	0.062
9.06	0.032
10.07	0.032
11.07	0.049
12.05	0.036

CURVE 5 (CONT.)

λ	ε
13.05	0.040
14.06	0.049
15.06	0.069

CURVE 6
T = 303.

λ	ε
7.15	0.060
8.12	0.050
9.06	0.042
10.07	0.025
11.07	0.042
12.05	0.042
13.05	0.023
14.06	0.038
15.06	0.047

CURVE 7
T = 301.

λ	ε
1.50	0.243
2.16	0.213
2.86	0.191
3.60	0.166
4.32	0.144
5.31	0.120
6.18	0.103
7.05	0.088
7.97	0.075
8.80	0.065
9.63	0.058
10.39	0.058
11.39	0.053
13.06	0.050
14.31	0.050
16.05	0.050
18.39	0.050
21.00	0.050

b. Normal Spectral Emittance (Temperature Dependence)

There are no experimental data located in the literature. The provisional values tabulated in Table 1-4 and shown in Figure 1-6 were calculated with the relation discussed in subsection 4.20, based on Eq. (2.5-5), for highly polished alclad Aluminum Alloy 2024 for wavelengths of 2.8, 3.8, 5.0, and 10.6 μm. These values are believed accurate to ±20% over the entire wavelength range.

TABLE 1-4. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM ALLOY 2024 (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

T	ε	T	ε	T	ε	T	ε
HIGHLY POLISHED ALCLAD λ = 2.8		HIGHLY POLISHED ALCLAD λ = 3.8		HIGHLY POLISHED ALCLAD λ = 5.0		HIGHLY POLISHED ALCLAD λ = 10.6	
250.0	0.054	250.0	0.038	250.0	0.030	250.0	0.019
293.0	0.057	293.0	0.041	293.0	0.033	293.0	0.021
300.0	0.057	300.0	0.041	300.0	0.033	300.0	0.021
350.0	0.060	350.0	0.044	350.0	0.036	350.0	0.023
400.0	0.062	400.0	0.046	400.0	0.038	400.0	0.024
450.0	0.063	450.0	0.043	450.0	0.040	450.0	0.026
500.0	0.065	500.0	0.050	500.0	0.041	500.0	0.027
550.0	0.066	550.0	0.052	550.0	0.043	550.0	0.028
600.0	0.067	600.0	0.053	600.0	0.044	600.0	0.029
650.0	0.068	650.0	0.055	650.0	0.046	650.0	0.030
700.0	0.068	700.0	0.056	700.0	0.047	700.0	0.031
750.0	0.069	750.0	0.057	750.0	0.048	750.0	0.032

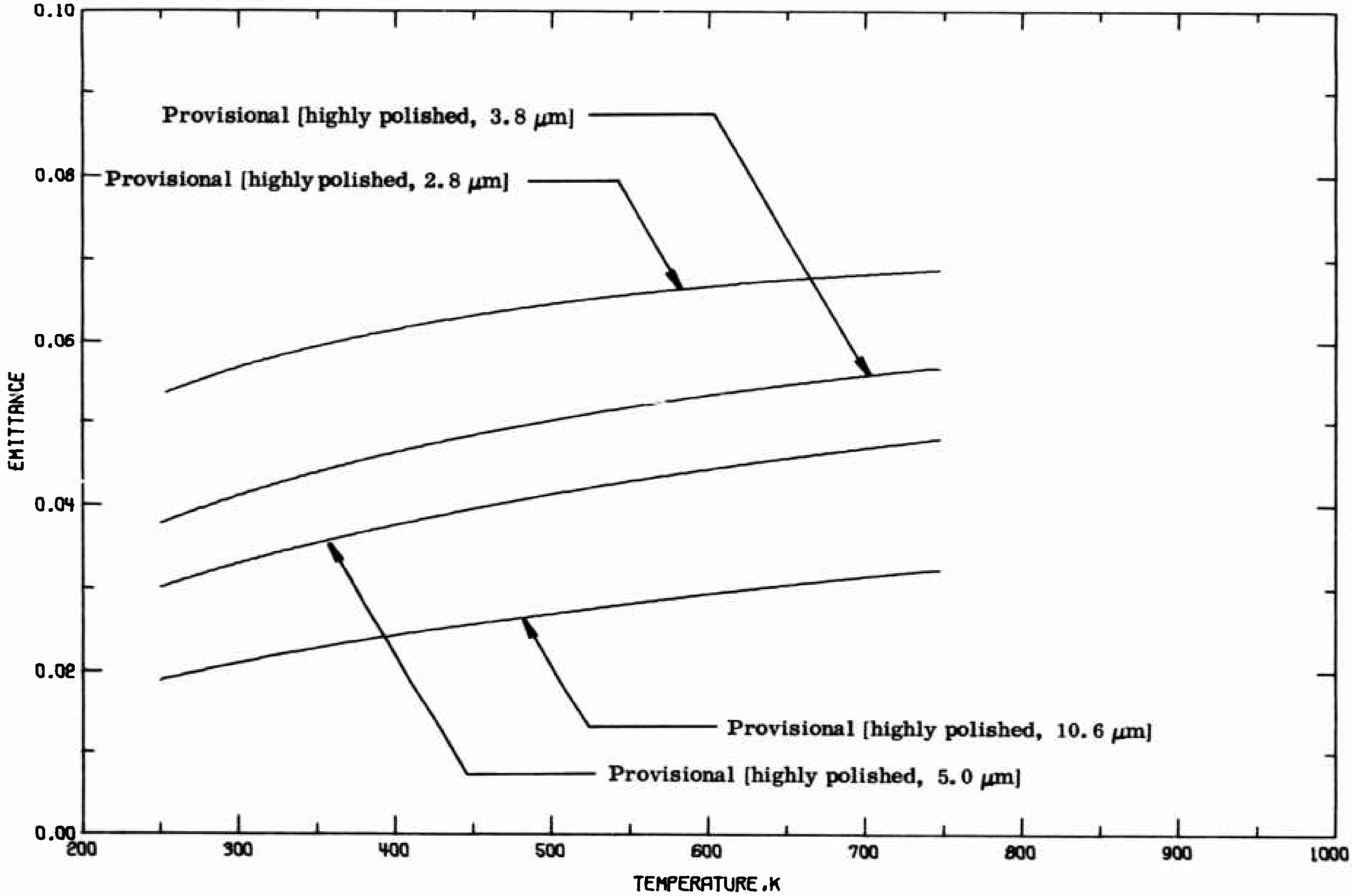


FIGURE 1-6. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ALCLAD ALUMINUM ALLOY 2024 (TEMPERATURE DEPENDENCE).

c. Angular Spectral Emittance (Wavelength Dependence)

There are no data available for this subproperty but the provisional values listed in Table 1-5 and shown in Figures 1-7, 1-8, and 1-9 for anodized, alodined ($\theta = 15^{\circ}$), and alodined ($\theta = 45^{\circ}$) Aluminum Alloy 2024, respectively, were calculated from the angular spectral reflectance data (see Section 4.1.f). These values are believed accurate to ± 15% over the entire wavelength range for the anodized and alodined Aluminum Alloy 2024 ($\theta = 15^{\circ}$) materials at 293 K. The provisional values for alodined Aluminum Alloy 2024 ($\theta = 45^{\circ}$) are accurate to ± 20%.

There are several methods which can be used to produce an anodized surface. The angular spectral emittance can vary widely with the anodizing process, i. e., porous or hard, secondary treatments such as sealing or dying of the surface layer, and thickness. Most of the authors do not clearly specify the nature of the anodizing process or surface conditions. So the provisional values reported in Table 1-5 are applicable only to the sulfuric acid anodized surface. Similarly, there are several alodining processes. Depending on this process the angular spectral emittance may vary. The provisional values apply only to the chromate conversion coating used in the references.

TABLE 1-5. PROVISIONAL ANGULAR SPECTRAL EMITTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
SULFURIC ACID ANODIZED, θ =15° T = 293		SULFURIC ACID ANODIZED, θ=15° T = 293 (CONT.)		CHROMATE ALODINED, θ=15° T = 293		CHROMATE ALODINED, θ=15° T = 293 (CONT.)		CHROMATE ALODINED, θ=45° T = 293	
0.30	0.743	6.10	0.484	2.34	0.517	12.00	0.142	2.00	0.240
0.35	0.640	6.20	0.473	2.50	0.531	12.50	0.135	2.20	0.258
0.40	0.553	6.40	0.410	2.80	0.604	13.00	0.129	2.40	0.288
0.50	0.482	6.60	0.398	3.00	0.677	13.50	0.123	2.60	0.358
0.60	0.474	6.80	0.405	3.05	0.685	14.00	0.118	2.80	0.552
0.70	0.475	7.00	0.426	3.10	0.689	14.50	0.113	3.00	0.620
0.80	0.481	7.20	0.514	3.15	0.688	15.00	0.109	3.10	0.618
0.83	0.482	7.40	0.640	3.20	0.682			3.20	0.606
0.90	0.434	7.60	0.740	3.25	0.673			3.40	0.550
1.00	0.380	7.80	0.820	3.30	0.655			3.60	0.470
1.20	0.320	8.00	0.875	3.50	0.589			3.80	0.408
1.40	0.292	8.20	0.918	3.70	0.528			4.00	0.366
1.60	0.274	8.40	0.942	3.80	0.508			4.20	0.338
1.80	0.268	8.60	0.949	4.00	0.480			4.40	0.320
2.00	0.279	8.80	0.947	4.20	0.458			4.50	0.316
2.20	0.301	9.00	0.940	4.50	0.431			4.60	0.320
2.40	0.341	9.20	0.920	4.56	0.426			4.70	0.400
2.60	0.422	9.40	0.893	4.61	0.427			4.72	0.412
2.80	0.779	9.60	0.864	4.70	0.461			4.76	0.414
2.85	0.807	9.80	0.855	4.74	0.478			4.80	0.412
2.90	0.810	10.00	0.864	4.77	0.481			4.90	0.320
2.95	0.808	10.20	0.900	4.81	0.472			5.00	0.298
3.00	0.797	10.40	0.935	4.87	0.440			5.20	0.280
3.20	0.677	10.60	0.960	4.93	0.405			5.40	0.270
3.40	0.592	10.80	0.972	4.95	0.397			5.60	0.260
3.60	0.526	11.00	0.975	5.00	0.394			5.80	0.252
3.80	0.484	11.20	0.963	5.50	0.362			6.00	0.246
4.00	0.454	11.40	0.955	6.00	0.334			7.00	0.220
4.20	0.428	11.60	0.949	6.50	0.308			8.00	0.200
4.40	0.410	11.80	0.943	7.00	0.285			9.00	0.181
4.60	0.396	12.00	0.938	7.50	0.263			10.00	0.164
4.80	0.389	12.50	0.928	8.00	0.244			10.60	0.156
5.00	0.384	13.00	0.920	8.50	0.227			11.00	0.150
5.20	0.382	13.50	0.915	9.00	0.210			12.00	0.136
5.40	0.390	14.00	0.909	9.50	0.195			13.00	0.127
5.60	0.406	14.50	0.905	10.00	0.182			14.00	0.116
5.80	0.442	15.00	0.902	10.60	0.167				
5.90	0.476			11.00	0.158				
6.00	0.484			11.50	0.150				

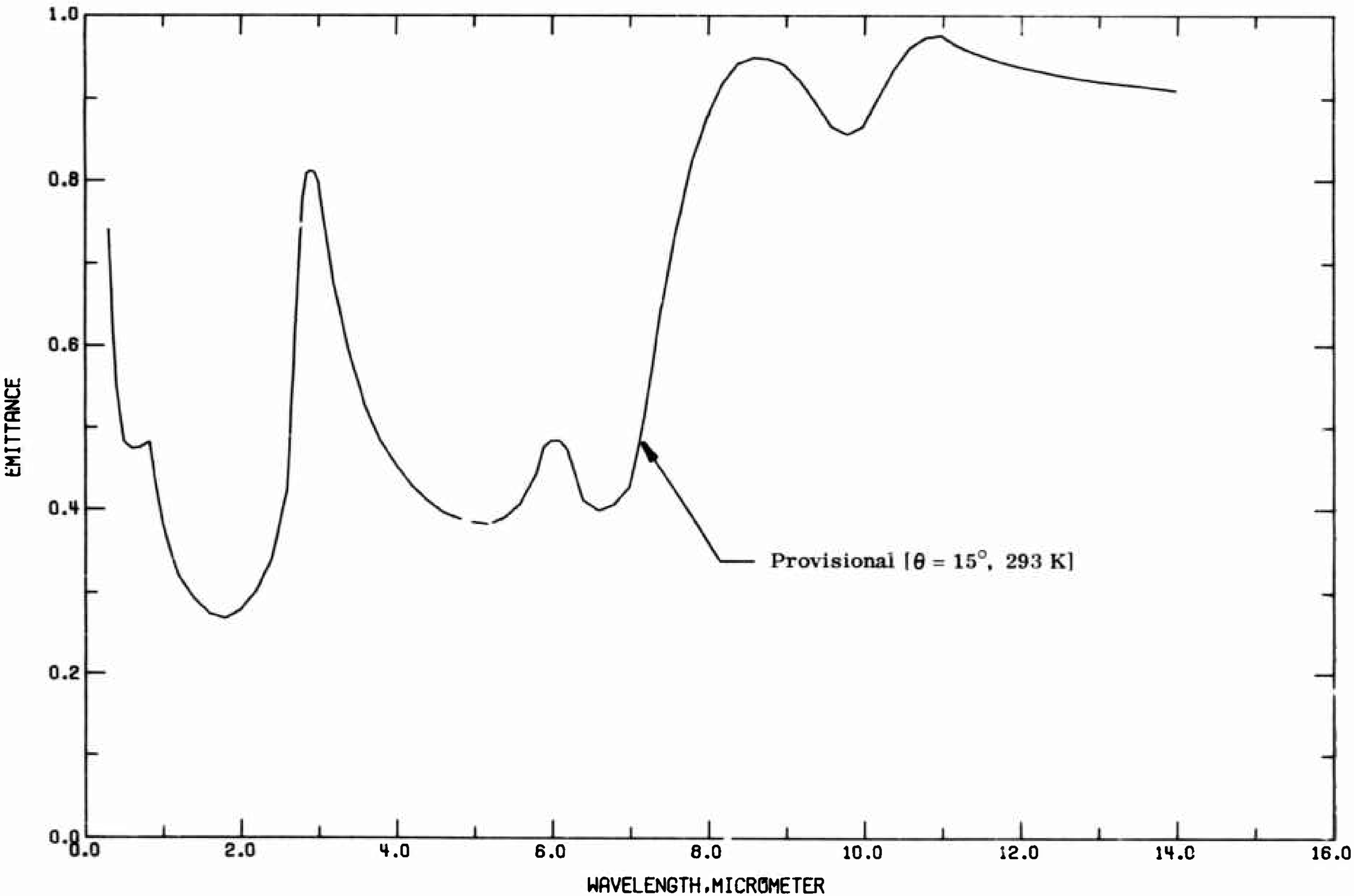


FIGURE 1-7. PROVISIONAL ANGULAR SPECTRAL EMITTANCE OF ANODIZED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

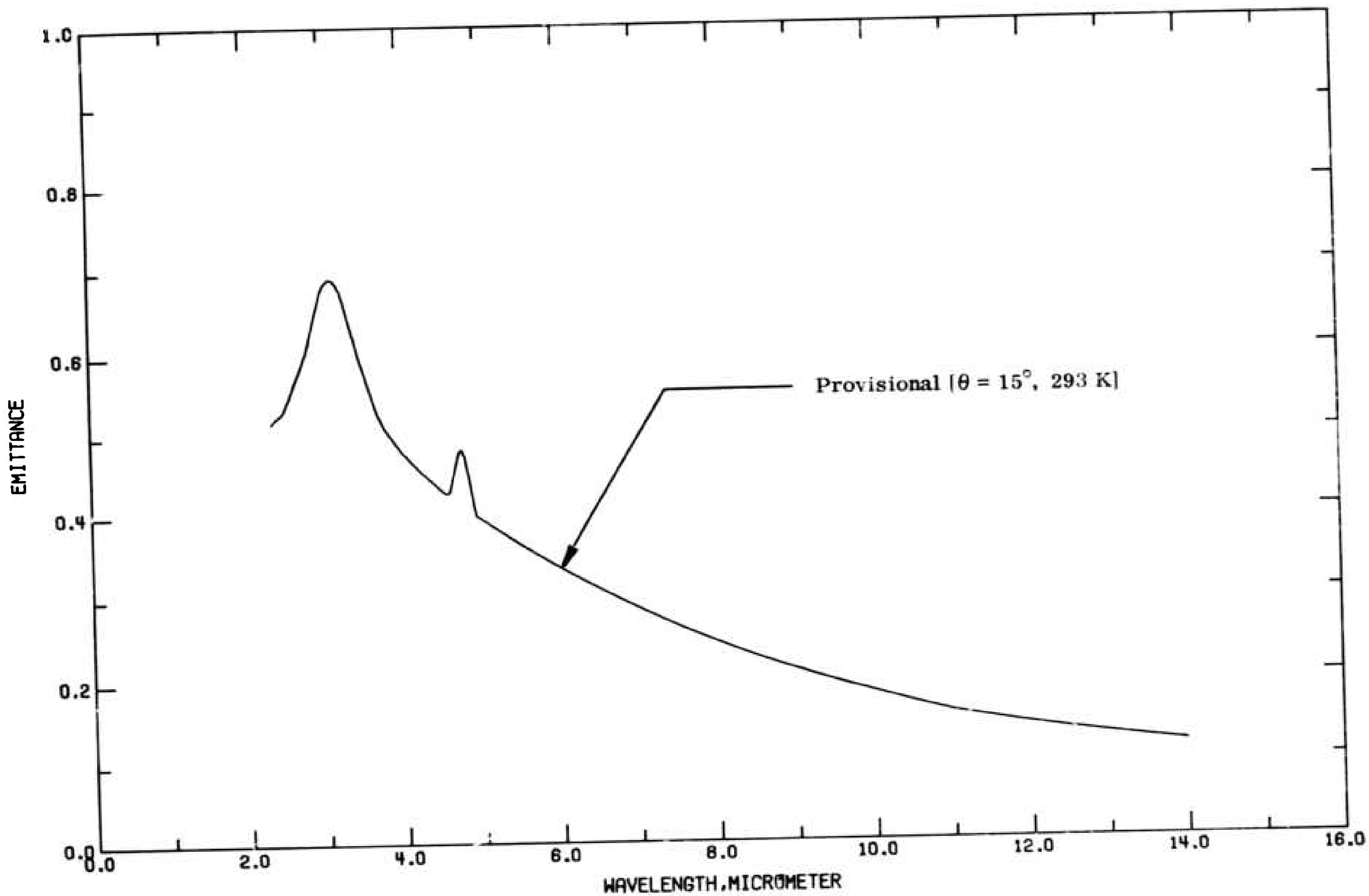


FIGURE 1-8. PROVISIONAL ANGULAR SPECTRAL EMITTANCE OF ALODINED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

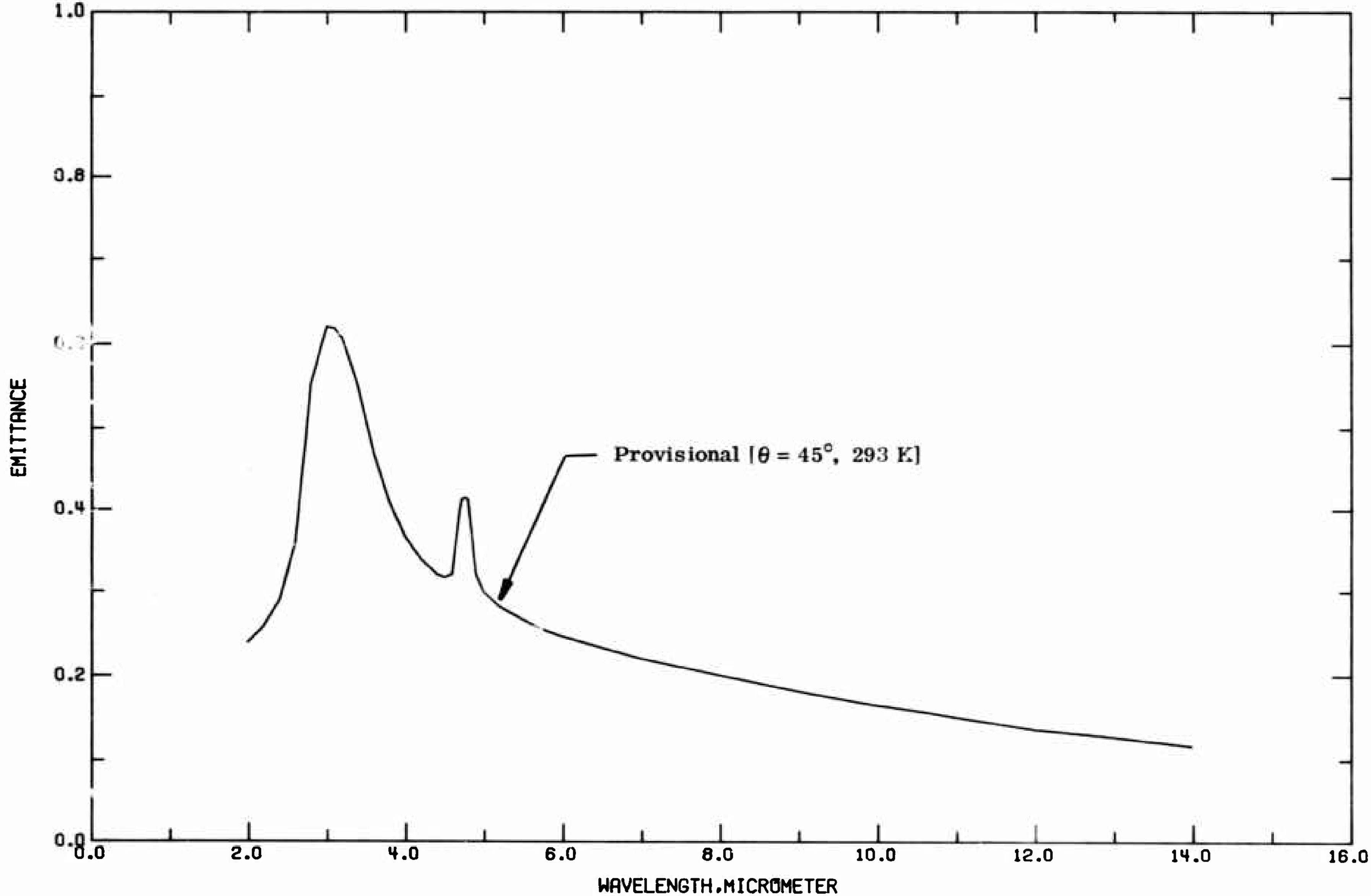


FIGURE 1-9. PROVISIONAL ANGULAR SPECTRAL EMITTANCE OF ALODINED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

d. Normal Spectral Reflectance (Wavelength Dependence)

There are 47 sets of experimental data available for the wavelength dependence (λ = 0.3-25.0 μm) of the normal spectral reflectance of Aluminum Alloy 2024 under various surface conditions. These are listed in Table 1-8 and most of them are shown in Figure 1-11. There are four sets of experimental data available for wavelength dependence (λ = 2.0-15.0 μm) of the normal spectral reflectance of polished alclad Aluminum Alloy 2024 shown in Figure 1-13. Out of the total 47 data sets, 15 sets are for a polished material. Most of the measurements are for wavelengths between 0.3-3.0 μm.

(1) Highly Polished Aluminum Alloy 2024

The recommended values at 293 K listed in Table 1-6 and plotted in Figure 1-10 are primarily from the investigation of Schriempf and Wieting [A00003] and are believed to be accurate to ± 10% over the entire wavelength range. These values are consistent with the normal spectral emittance measurements of the similar material.

(2) Alclad Aluminum Alloy 2024

There are four sets of data for the wavelength dependence (2.0-14.7 μm) of the angular spectral reflectance of alclad Aluminum Alloy 2024. These are shown in Figure 1-13 and listed in Table 1-8. The incident angle reported is 15°. The normal spectral reflectance values for an ideal aluminum surface calculated using the relation discussed in subsection 4.20 and based on Eq. (2.5-5) agree extremely well with experimental results. These recommended values are believed accurate to ± 10% over the entire wavelength range. The provisional values for highly polished alclad Aluminum Alloy 2024 reported at 450, 600, and 750 K shown in Figure 1-12 and listed in Table 1-6, were calculated from the relation discussed in subsection 4.20, based on Eq. (2.5-5). These values are believed accurate to ± 20%.

(3) Oxidized Aluminum Alloy 2024

The provisional values listed in Table 1-6 and shown in Figure 1-14 are for oxidized Aluminum Alloy 2024 at 823 K. These values are consistent with the provisional normal spectral emittance values (see Section 4.1a). These values are believed accurate to ± 20%.

TABLE 1-6. RECOMMENDED NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
HIGHLY POLISHED T = 293		HIGHLY POLISHED ALCLAD T = 293		HIGHLY POLISHED ALCLAD T = 450		HIGHLY POLISHED ALCLAD T = 600		HIGHLY POLISHED ALCLAD T = 750		OXIDIZED ALLOY T = 823	
2.20	0.9020	2.5	0.933	2.5	0.929A†	2.5	0.927A†	2.5	0.925A†	2.00	0.574A†
2.80	0.9240	2.8	0.943	2.8	0.937A	2.8	0.933A	2.8	0.931A	2.20	0.582A
3.00	0.9303	3.0	0.948	3.0	0.941A	3.0	0.937A	3.0	0.934A	2.50	0.590A
3.50	0.9425	3.5	0.956	3.5	0.948A	3.5	0.944A	3.5	0.940A	2.80	0.597A
3.80	0.9476	3.8	0.959	3.8	0.952A	3.8	0.947A	3.8	0.943A	3.00	0.601A
4.00	0.9502	4.0	0.961	4.0	0.954A	4.0	0.949A	4.0	0.945A	3.20	0.606A
4.50	0.9560	4.5	0.965	4.5	0.957A	4.5	0.953A	4.5	0.949A	3.50	0.614A
5.00	0.9598	5.0	0.967	5.0	0.960A	5.0	0.956A	5.0	0.952A	3.80	0.619A
5.50	0.9625	5.5	0.969	5.5	0.963A	5.5	0.958A	5.5	0.954A	4.00	0.624A
6.00	0.9645	6.0	0.971	6.0	0.965A	6.0	0.960A	6.0	0.957A	4.20	0.626A
6.50	0.9662	6.5	0.973	6.5	0.966A	6.5	0.962A	6.5	0.958A	4.50	0.634A
7.00	0.9677	7.0	0.974	7.0	0.968A	7.0	0.963A	7.0	0.960A	4.80	0.638A
7.50	0.9690	7.5	0.975	7.5	0.969A	7.5	0.965A	7.5	0.961A	5.00	0.640A
8.00	0.9702	8.0	0.976	8.0	0.970A	8.0	0.966A	8.0	0.963A	5.20	0.644A
8.50	0.9713	8.5	0.977	8.5	0.971A	8.5	0.967A	8.5	0.964A	5.50	0.649A
9.00	0.9722	9.0	0.977	9.0	0.972A	9.0	0.968A	9.0	0.965A	5.80	0.654A
9.50	0.9728	9.5	0.978	9.5	0.973A	9.5	0.969A	9.5	0.966A	6.00	0.658A
10.00	0.9730	10.0	0.979	10.0	0.974A	10.0	0.970A	10.0	0.967A	6.20	0.660A
10.60	0.9738	10.5	0.979	10.5	0.974A	10.5	0.971A	10.5	0.968A	6.50	0.664A
11.00	0.9742	11.0	0.980	11.0	0.975A	11.0	0.971A	11.0	0.968A	7.00	0.670A
11.50	0.9746	11.5	0.980	11.5	0.975A	11.5	0.972A	11.5	0.969A	7.20	0.672A
12.00	0.9750	12.0	0.981	12.0	0.976A	12.0	0.972A	12.0	0.970A	7.50	0.677A
12.50	0.9754	12.5	0.981	12.5	0.976A	12.5	0.973A	12.5	0.970A	8.00	0.683A
13.00	0.9758	13.0	0.981	13.0	0.977A	13.0	0.974A	13.0	0.971A	8.50	0.690A
13.50	0.9761	13.5	0.982	13.5	0.977A	13.5	0.974A	13.5	0.971A	9.00	0.697A
14.00	0.9765	14.0	0.982	14.0	0.978A	14.0	0.975A	14.0	0.972A	9.50	0.704A
14.50	0.9768	14.5	0.983	14.5	0.978A	14.5	0.975A	14.5	0.972A	10.00	0.710A
15.00	0.9772	15.0	0.983	15.0	0.979A	15.0	0.975A	15.0	0.973A	10.50	0.716A
										11.00	0.723A
										11.50	0.729A
										12.00	0.734A
										12.50	0.739A
										13.00	0.744A
										13.50	0.748A
										14.00	0.752A

†VALUE FOLLOWED BY AN "A" IS PROVISIONAL.

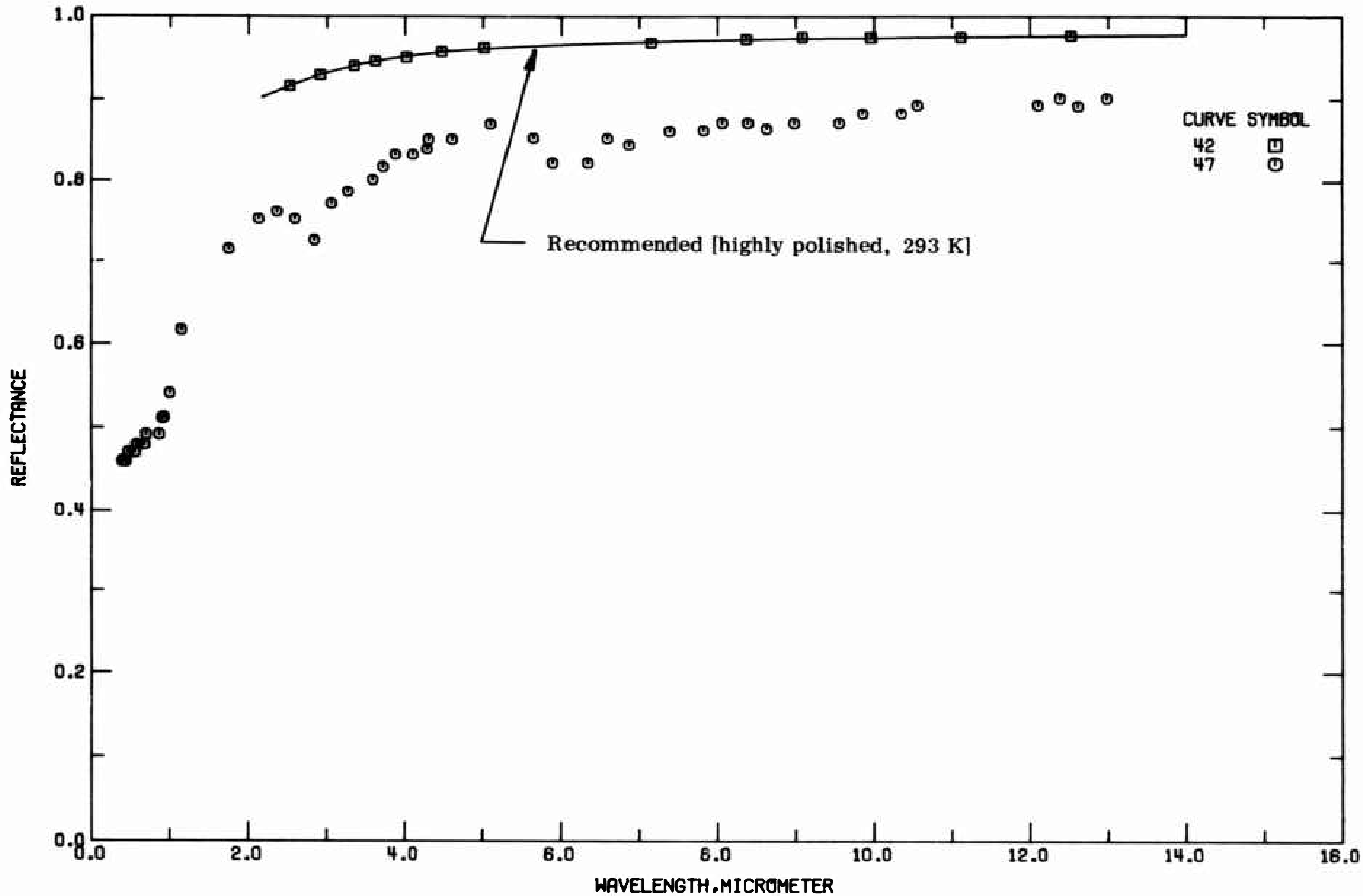


FIGURE 1-10. RECOMMENDED NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

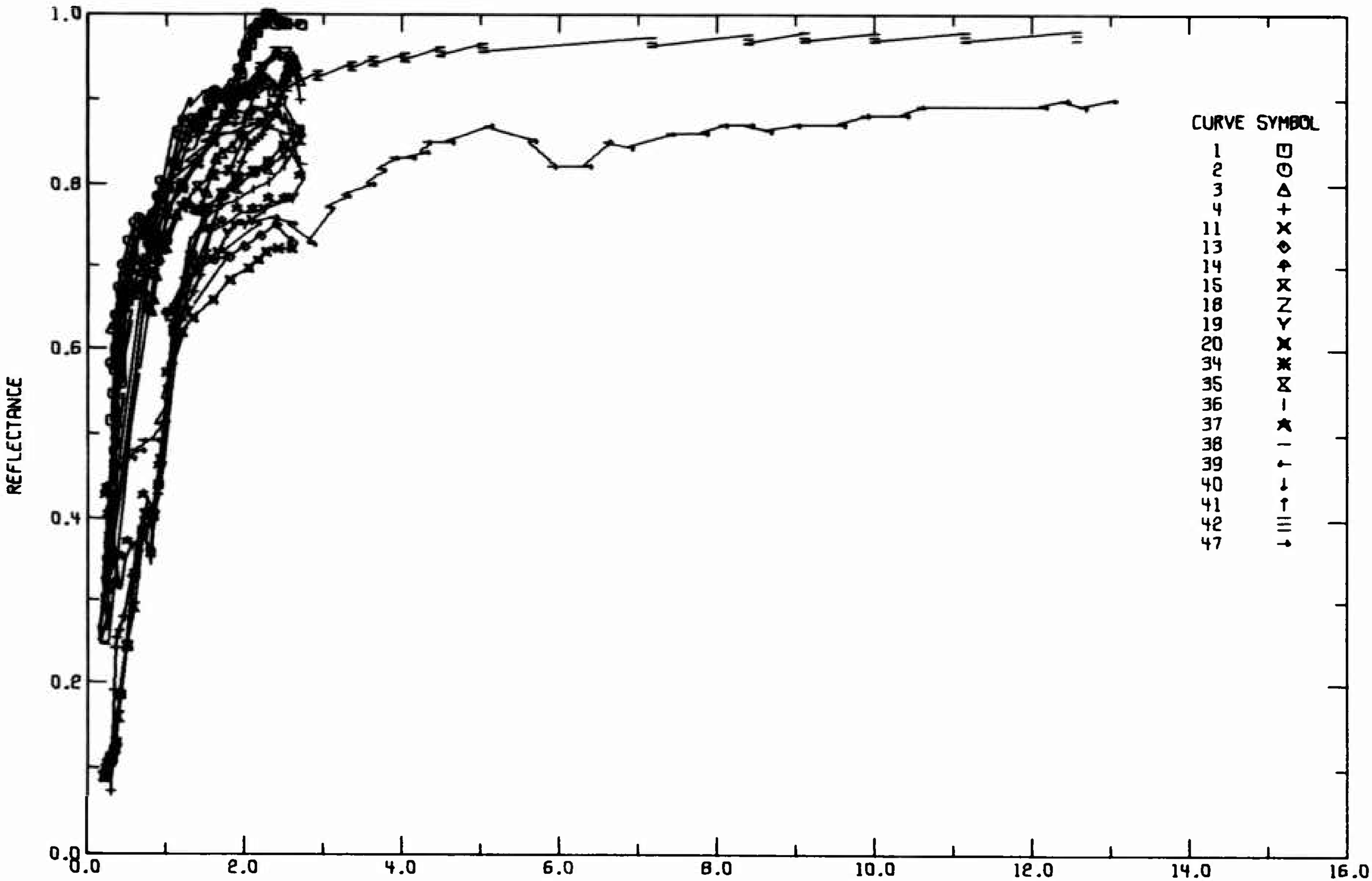


FIGURE 1-11. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

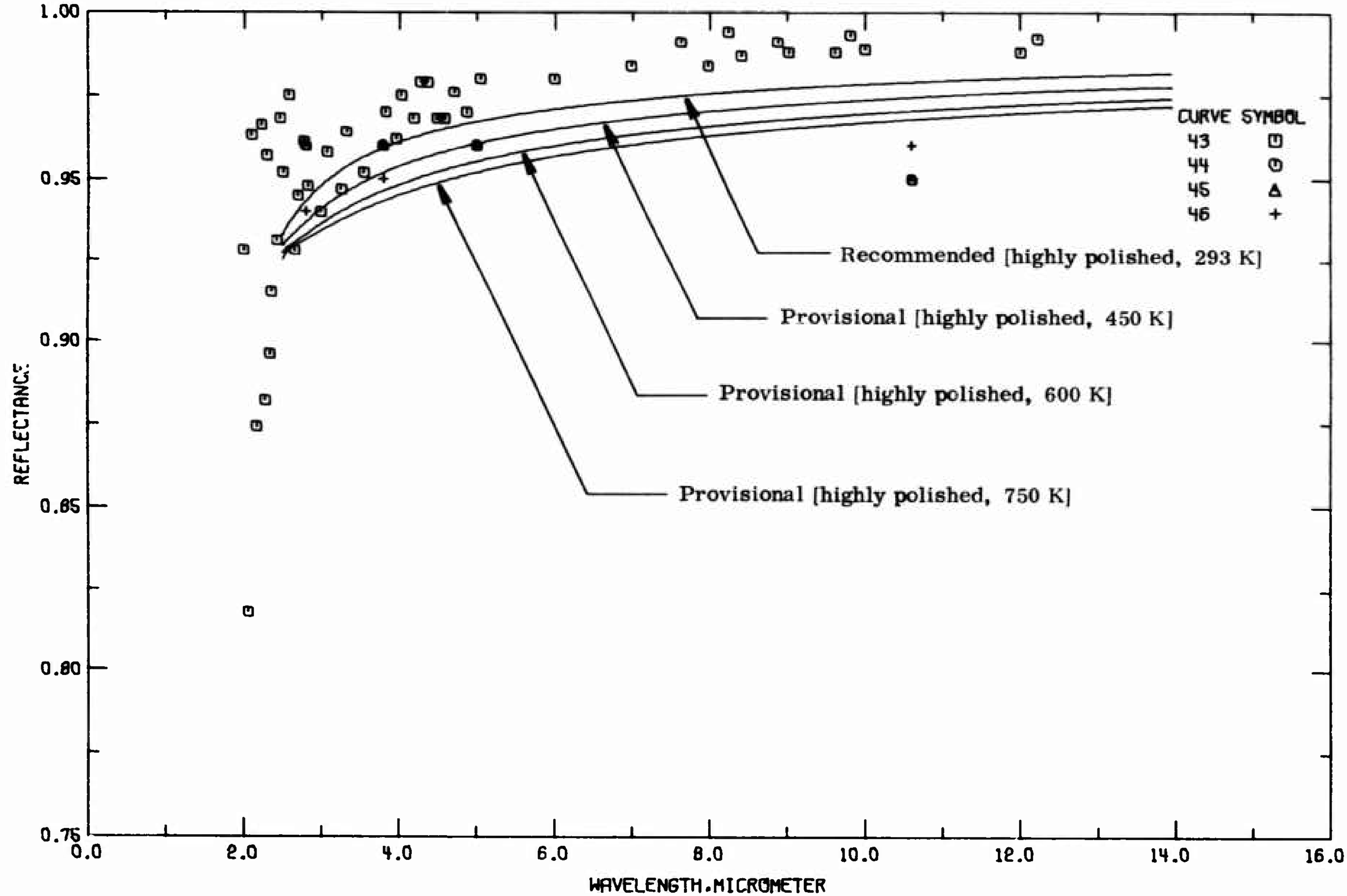


FIGURE 1-12. RECOMMENDED NORMAL SPECTRAL REFLECTANCE OF ALCLAD ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

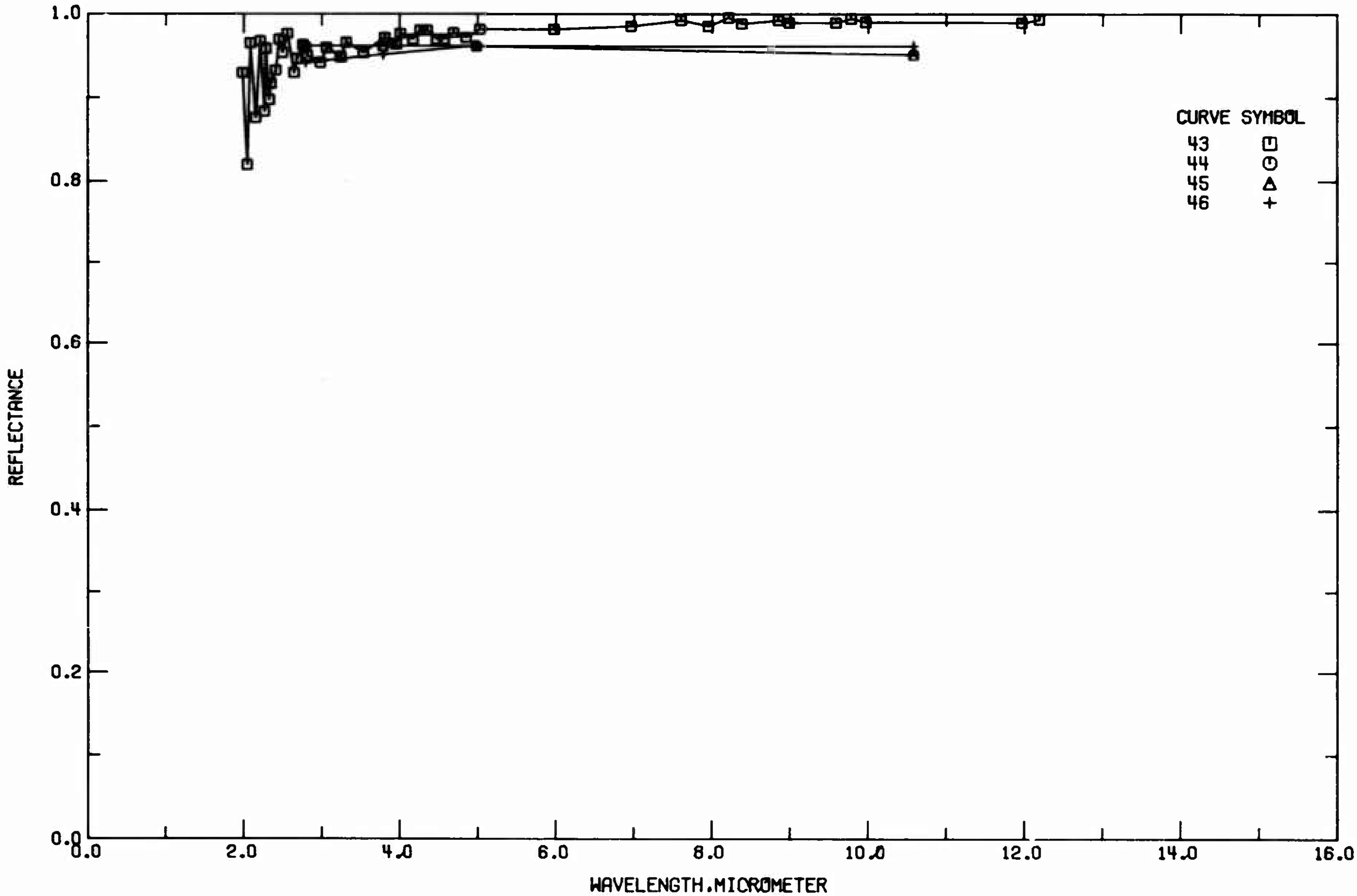


FIGURE 1-13. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALCLAD ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

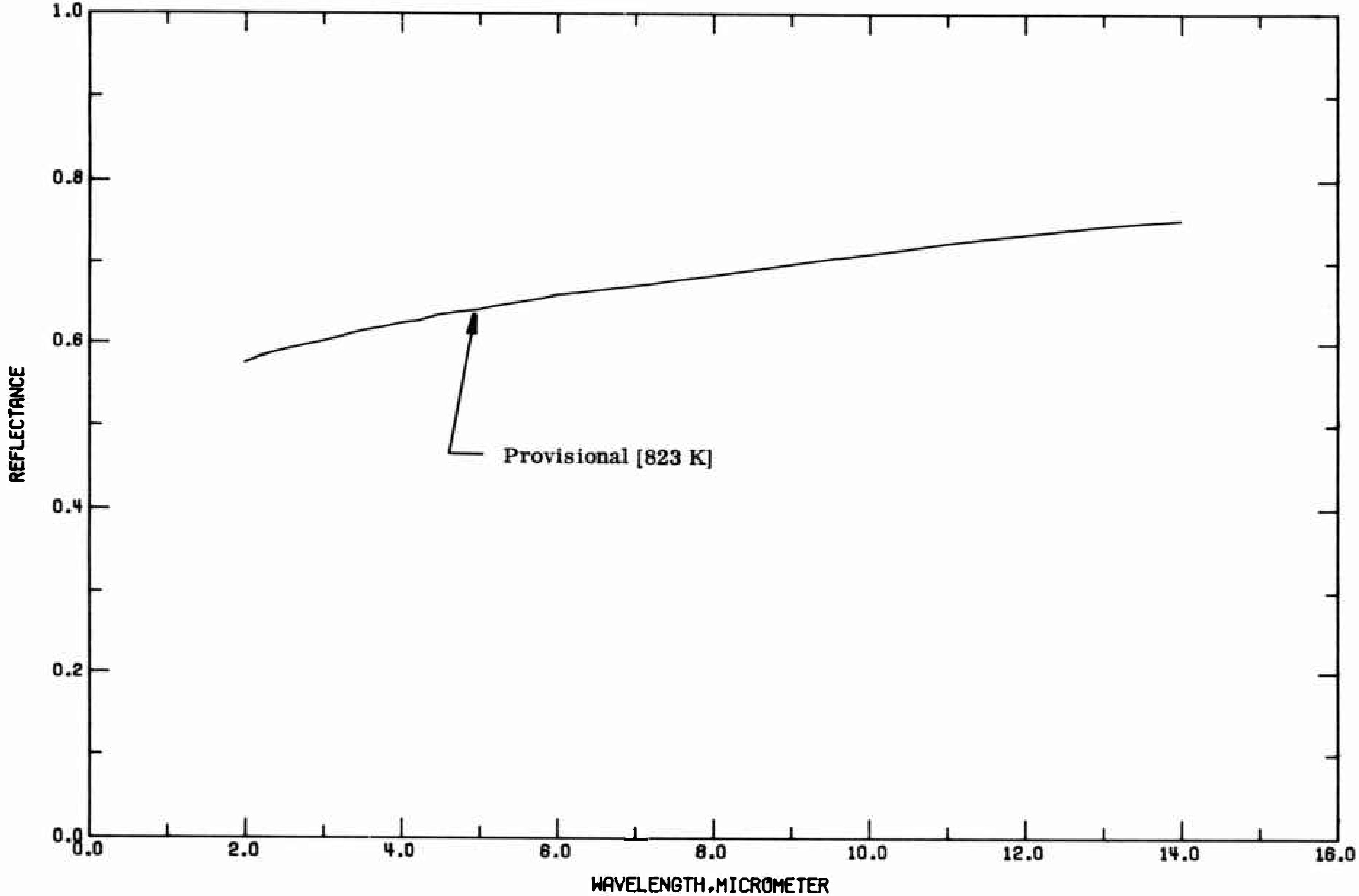


FIGURE 1-14. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF OXIDIZED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

TABLE 1-7. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T06979	Betz, H.T., Morris, J.C., Olson, O.H., and Schurin, B.D.	1957	0.3-2.7	293	Aluminum 24-ST	Surface conditions as received from supplier, may include oily film or plain dirt; a General Electric Recording Spectrophotometer is used in visible range and an integrating sphere reflectometer is used for ultraviolet and infrared region; magnesium carbonate block used for standard; smooth values extracted from figure; measurement temperature not given explicitly, assumed to be 293 K; θ=6° in visible region, θ=9° in ultraviolet and infrared region; reported error ±4%.
2	T06979	Betz, H.T., et al.	1957	0.3-2.7	293	Aluminum 24-ST	Similar to the above specimen except sample cleaned with liquid detergent to remove superficial dirt and oil films.
3	T06979	Betz, H.T., et al.	1957	0.3-2.7	293	Aluminum 24-ST	Similar to the above specimen except sample polished with fine polishing compound on buffing wheel.
4	T06979	Betz, H.T., et al.	1957	0.3-2.7	293	Aluminum 24-ST	Similar to the above specimen except sample allowed to oxidize in air at red heat for 30 min.
5	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 7	Specimen was 15/16" x 1" x 1" with symmetric V-grooves cut into one 15/16" x 1" face; grooved surfaces made for this study with ruling machine of type used by Bausch and Lomb, Inc.; specifications of grooved profiles and angle so reported by manufacturer, valley to valley distance (w), 83.33 μm, peak to valley height (h), 24.4 μm, and angle between faces, 119°15'; source used is G.E. 30A/T20/4 tungsten ribbon strip lamp enclosed in H_2O cooled shield, monochromator used was Perkin-Elmer Model 83, detectors used were RCA 1P28 photomultiplier tube for visible (0.2-0.7 μm) and Perkin-Elmer lead sulfide photoconducting cell for near infrared (0.4-2.8 μ); incident beam and viewing path was perpendicular to groove; angle θ' said to be negative if measured in same direction from normal as θ; θ' uncertainty ±1°; reference was standard mirror; specimen appeared "bright and shining" to eye; measured temperature specified as room temperature, 293 K assigned; θ=0°, θ'=59°.
6	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 7	The above specimen except θ'=-60°.
7	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 8	Similar to the above specimen except θ'=59°.
8	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 8	The above specimen except θ'=-60°.
9	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 9	Similar to the above specimen except w = 16.67 μm, h = 4.9 μm, the angle of the V-groove = 119°6'; θ'=58.0°.
10	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 9	The above specimen except θ'=-59.5°.
11	T29563	Eberhart, R.C.	1960	1.0-2.6	293	Aluminum 24ST, Polished	Specimen 2.22 cm discs, 0.16 to 0.32 cm thick; sample surface prepared by standard metallographic techniques, average horizontal peak to peak distance, 30 μm, groove depth is 0.40 μm; integrating sphere used with PbS detector; reference standard MgO; data extracted from figure; measurement temperature not given explicitly, 293 K assigned; θ=5°, ω'=2π.
12	T29563	Eberhart, R.C.	1960	0.4-1.0	293	Aluminum 24ST, Polished	Similar to the above specimen except a phototube detector (RCA PM 128 photomultiplier tube) was used with an integrating sphere.

TABLE 1-7. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
13	T29563	Eberhart, R.C.	1960	1.0-2.6	293	Aluminum 24ST, Polished	Similar to the above specimen except a Beckman DK-2 spectrophotometer was used for measurement; states values were uncorrected; reported error 10-15%.
14	T29563	Eberhart, R.C.	1960	1.0-2.6	293	Aluminum 24ST, Polished	Similar to specimen in curve 11.
15	T29563	Eberhart, R.C.	1960	1.0-2.6	293	Aluminum 24ST, Polished	Similar to the above specimen but a Beckman DK-2 spectrophotometer was used for measurement; states values were corrected.
16	T29563	Eberhart, R.C.	1960	1.2, 1.8	293	Aluminum 24ST, Polished	Similar to specimen in curve 11 except $\theta=0°$.
17	T29563	Eberhart, R.C.	1960	1.2, 1.8	293	Aluminum 24ST, Polished	Similar to the above specimen except $\theta=10°$.
18	T29563	Eberhart, R.C.	1960	1-2.6	293	Aluminum 24ST, Polished	Similar to the above specimen except data extracted from smooth curve; $\theta=5°$.
19	T29563	Eberhart, R.C.	1960	1-2.6	293	Aluminum 24ST, Grade 1	Similar to the above specimen except average horizontal peak to peak distance, 7 μm, groove depth (average displacement from mean surface line) is 3.48 μm; sample surface prepared with sandpaper; data extracted from smooth curve.
20	T29563	Eberhart, R.C.	1960	1-2.6	293	Aluminum 24ST, Grade 2	Similar to the above specimen except average horizontal peak to peak distance, 10 μm, groove depth (average displacement from mean surface line) is 4.52 μm; sample surface prepared with sandpaper; data extracted from smooth curve.
21	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to specimen in curve 11 except data extracted from smooth curve; $\theta=0°$.
22	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except $\theta=5°$.
23	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except $\theta=10°$.
24	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except average horizontal peak to peak distance, 7 μm, groove depth (average displacement from mean surface line) is 3.48 μm; sample surface prepared with sandpaper; data extracted from smooth curve; $\theta=0°$.
25	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except $\theta=5°$.
26	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except $\theta=10°$.
27	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except average horizontal peak to peak distance, 10 μm, groove depth (average displacement from mean surface line) is 4.52 μm; sample surface prepared with sandpaper; data extracted from smooth curve; $\theta=0°$.
28	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except $\theta=5°$.
29	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except $\theta=10°$.

TABLE 1-7. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
30	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Polished; Beckman DK-2 spectrometer integrating sphere used for measurement; MgO reference standard; data extracted from figure; measurement temperature not given explicitly, 293 K assigned; $\theta=0°$, $\omega'=2\pi$.
31	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except $\theta=10°$.
32	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Roughened sample; surface roughened with sandpaper, scratches parallel, course structure-peak to peak depth-6.35 μm, spacing-34 μm; fine structure-peak to peak depth-1 μm; Beckman DK-2 spectrometer integrating sphere used for measurement; MgO reference standard; data extracted from figure; measurement temperature not given explicitly, 293 K assigned; $\theta=0°$, $\omega'=2\pi$.
33	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except $\theta=10°$.
34	T24808	Alexander, A.L., Cowling, J.E., and Noonam, F.M.	1961	0.22-2.7	293	Aluminum Alloy 24S-T	Sample anodized; specimen irradiated in vacuum $\leq 1 \times 10^{-5}$ mm Hg at level of 0.75 cal/min for 100 hr; measurements made with Beckman DK-2 Spectrophotometer; data extracted from figure; measurement temperature not explicitly given, 293 K assigned; normal reflectance assumed; $\theta\sim0°$.
35	T24808	Alexander, A.L., et al.	1961	0.20-2.7	293	Aluminum Alloy 24S-T	Similar to the above specimen except irradiation applied for 60 hr.
36	T24808	Alexander, A.L., et al.	1961	0.22-2.7	293	Aluminum Alloy 24S-T	Similar to the above specimen except irradiation applied for 20 hr.
37	T24808	Alexander, A.L., et al.	1961	0.22-2.7	293	Aluminum Alloy 24S-T	Similar to the above specimen except not exposed to irradiation.
38	T24808	Alexander, A.L., et al.	1961	0.22-2.7	293	Aluminum Alloy 24S-T	Sample clean rolled; specimen irradiated in vacuum $\leq 1 \times 10^{-5}$ mm Hg at level of 0.75 cal/min for 100 hr; measurements made with Beckman DK-2 spectrophotometer; data extracted from figure; measurement temperature not explicitly given, 293 K assumed; normal reflectance assumed; $\theta\sim0°$.
39	T24808	Alexander, A.L., et al.	1961	0.22-2.7	293	Aluminum Alloy 24S-T	Similar to the above specimen except irradiation applied for 60 hr.
40	T24808	Alexander, A.L., et al.	1961	0.22-2.7	293	Aluminum Alloy 24S-T	Similar to the above specimen except irradiation applied for 20 hr.
41	T24808	Alexander, A.L., et al.	1961	0.22-2.7	293	Aluminum Alloy 24S-T	Similar to the above specimen except not exposed to irradiation.
42	A00003	Schriempf, J.T. and Wieting, T.J.	1974	2.53-20.0	293	Aluminum Alloy	Author states specimen was "aluminum alloy very similar to 2024 aluminum"; author describes surface as "high quality"; reflectance measured using grating spectrometer; a gold reference mirror was used as a standard; data extracted from figure; measurement temperature specified as room temperature, 293 K assigned; $\theta\sim0°$, reported error $\pm$ 0.1%.

TABLE 1-7. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
43	A00001	Grimm, F.C. and Fannin, E.R.	1972	2-14.7	293	2024-T81 Alclad, Sample No. B-1	Polished; sample thickness 99.0 x 10^{-3} cm; samples prepared by Organic Chemistry Laboratory of Dept. 256; measurements made with a Dunn Associates ellipsoidal mirror reflectometer; measurement temperature specified as ambient temperature, 293 K assigned; data extracted from smooth curve; relative reflectance reported, multiplied by 0.95 to convert to absolute (gold reference standard used); θ=15°, $\omega'=2\pi$.
44	A00001	Grimm, F.C. and Fannin, E.R.	1972	2.8-10.6	293	2024-T81 Alclad, Sample No. B-1	The above specimen; reported values different from the values of above specimen for unknown reason.
45	A00001	Grimm, F.C. and Fannin, E.R.	1972	2.8-10.6	293	2024-T81 Alclad, Sample No. B-1	The above specimen.
46	A00001	Grimm, F.C. and Fannin, E.R.	1972	2.8-10.6	293	2024-T81 Alclad, Sample No. B-1	The above specimen except sample heat treated by heating to 644 K for 1 hr in air; absolute reflectance reported; data extracted from table.
47	T40746	Shipley, W.S. and Thostesen, T.O.	1960	0.4-25.0	293	2024-T3 Aluminum Sample S4	"125" finish; measurement temperature not given explicitly, 293 K assigned; data extracted from smooth curve; normal reflectance assumed; $\theta\sim0°$, $\omega'=2\pi$.

TABLE 1-8. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 293.	
0.300	0.515
0.320	0.547
0.339	0.575
0.361	0.598
0.397	0.638
0.427	0.666
0.466	0.685
0.506	0.701
0.560	0.719
0.640	0.738
0.724	0.738
0.775	0.726
0.811	0.719
0.851	0.736
0.893	0.756
0.928	0.782
1.017	0.795
1.113	0.822
1.228	0.857
1.310	0.862
1.370	0.867
1.445	0.873
1.506	0.881
1.570	0.893
1.621	0.902
1.729	0.902
1.795	0.898
1.838	0.898
1.890	0.910
1.945	0.930
2.003	0.952
2.064	0.955
2.142	0.979
2.214	0.989
2.275	1.000
2.324	1.000
2.377	0.987
2.458	0.990
2.516	0.988

λ	ρ
CURVE 1 (CONT.)	
2.705	0.987
CURVE 2	
T = 293.	
0.300	0.581
0.357	0.638
0.399	0.672
0.450	0.700
0.523	0.729
0.598	0.752
0.654	0.758
0.708	0.752
0.766	0.735
0.793	0.727
0.822	0.731
0.842	0.747
0.886	0.784
0.930	0.803
1.013	0.799
1.087	0.824
1.171	0.857
1.217	0.874
1.330	0.876
1.415	0.876
1.476	0.883
1.538	0.897
1.584	0.906
1.626	0.909
1.799	0.910
1.846	0.917
1.914	0.935
1.980	0.953
2.015	0.963
2.054	0.971
2.107	0.981
2.166	0.988
2.204	0.989
2.214	0.989
2.275	1.000

λ	ρ
CURVE 2 (CONT.)	
2.324	1.000
2.377	0.987
2.458	0.990
2.516	0.988
2.705	0.987
CURVE 3	
T = 293.	
0.300	0.623
0.379	0.633
0.449	0.648
0.506	0.657
0.576	0.665
0.614	0.672
0.685	0.672
0.725	0.668
0.772	0.647
0.805	0.645
0.838	0.659
0.873	0.687
0.908	0.710
0.944	0.720
1.006	0.736
1.134	0.762
1.232	0.777
1.289	0.777
1.352	0.769
1.409	0.767
1.452	0.773
1.510	0.790
1.568	0.812
1.629	0.830
1.707	0.837
1.833	0.844
1.959	0.861
2.035	0.882
2.115	0.907
2.170	0.918
2.218	0.926

λ	ρ
CURVE 3 (CONT.)	
2.299	0.922
2.360	0.917
2.413	0.910
2.456	0.917
2.516	0.931
2.552	0.941
2.611	0.950
2.653	0.941
2.700	0.922
CURVE 4	
T = 293.	
0.300	0.072
0.336	0.190
0.353	0.242
0.367	0.254
0.404	0.263
0.457	0.279
0.569	0.324
0.640	0.360
0.705	0.378
0.792	0.393
0.845	0.408
0.890	0.429
0.941	0.465
0.989	0.514
1.022	0.556
1.065	0.582
1.116	0.606
1.181	0.633
1.251	0.649
1.345	0.668
1.430	0.688
1.505	0.717
1.591	0.749
1.663	0.773
1.734	0.785
1.827	0.797
1.883	0.807

λ	ρ
CURVE 4 (CONT.)	
1.956	0.826
2.026	0.842
2.116	0.851
2.211	0.859
2.281	0.869
2.351	0.880
2.414	0.894
2.470	0.912
2.522	0.926
2.562	0.936
2.603	0.943
2.642	0.929
2.700	0.899
CURVE 5*	
T = 293.	
0.5	0.237
1.5	0.342
CURVE 6*	
T = 293.	
0.5	0.440
1.5	0.378
CURVE 7*	
T = 293.	
0.5	0.36
1.5	0.25
CURVE 8*	
T = 293.	
0.5	0.202
1.5	0.246

λ	ρ
CURVE 9*	
T = 293.	
0.5	0.183
CURVE 10*	
T = 293.	
0.5	0.226
CURVE 11	
T = 293.	
1.00	0.764
1.20	0.794
1.40	0.824
1.60	0.850
1.80	0.887
2.00	0.904
2.20	0.932
2.40	0.951
2.60	0.941
CURVE 12*	
T = 293.	
0.40	0.554
0.60	0.584
0.80	0.615
1.00	0.625
CURVE 13	
T = 293.	
1.00	0.642
1.20	0.665
1.40	0.695
1.60	0.706
1.80	0.710
2.00	0.723
2.20	0.736
2.40	0.750

* NOT SHOWN IN FIGURE.

TABLE 1-8. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 13 (CONT.)	
2.60	0.729
CURVE 14 T = 293.	
1.00	0.767
1.20	0.796
1.40	0.827
1.60	0.856
1.80	0.891
2.00	0.914
2.20	0.936
2.40	0.955
2.60	0.942
CURVE 15 T = 293.	
1.00	0.721
1.20	0.772
1.40	0.796
1.60	0.811
1.80	0.815
2.00	0.856
2.20	0.872
2.40	0.887
2.60	0.934
CURVE 16* T = 293.	
1.2	0.794
1.8	0.882
CURVE 17* T = 293.	
1.2	0.822
1.8	0.914
CURVE 18 T = 293.	
1.00	0.764
1.20	0.800
1.40	0.828
1.60	0.855
1.80	0.879
2.00	0.907
2.20	0.937
2.38	0.955
2.53	0.955
2.60	0.946
CURVE 19 T = 293.	
1.00	0.638
1.24	0.680
1.48	0.707
1.66	0.715
1.78	0.739
1.87	0.750
2.00	0.750
2.09	0.755
2.24	0.769
2.60	0.783
CURVE 20 T = 293.	
1.00	0.572
1.20	0.619
1.34	0.636
1.60	0.658
1.81	0.682
2.05	0.697
2.17	0.707
2.27	0.717
2.42	0.721
2.60	0.721
CURVE 21* T = 293.	
1.2	0.775
CURVE 22* T = 293.	
1.2	0.806
CURVE 23* T = 293.	
1.2	0.840
CURVE 24* T = 293.	
1.2	0.654
CURVE 25* T = 293.	
1.2	0.665
CURVE 26* T = 293.	
1.2	0.678
CURVE 27* T = 293.	
1.2	0.581
CURVE 28* T = 293.	
1.2	0.594
CURVE 29* T = 293.	
1.2	0.606
CURVE 30* T = 293.	
1.2	0.794
CURVE 31* T = 293.	
1.2	0.824
CURVE 32* T = 293.	
1.2	0.661
CURVE 33* T = 293.	
1.2	0.680
CURVE 34 T = 293.	
0.220	0.087
0.240	0.097
0.260	0.103
0.280	0.106
0.300	0.107
0.320	0.111
0.340	0.120
0.360	0.129
0.420	0.185
0.500	0.243
0.600	0.332
0.700	0.386
0.800	0.358
0.834	0.402
CURVE 34 (CONT.)	
0.900	0.440
1.100	0.620
1.326	0.712
1.525	0.770
1.715	0.787
1.894	0.808
2.118	0.814
2.295	0.827
2.491	0.846
2.691	0.865
CURVE 35 T = 293.	
0.200	0.089
0.301	0.107
0.400	0.159
0.500	0.244
0.600	0.291
0.724	0.405
0.821	0.405
0.926	0.468
1.103	0.646
1.304	0.712
1.500	0.769
1.699	0.788
1.900	0.795
2.099	0.814
2.294	0.818
2.497	0.836
2.711	0.853
CURVE 36 T = 293.	
0.220	0.100
0.240	0.112
0.260	0.112
0.280	0.117
0.300	0.120
CURVE 36 (CONT.)	
0.320	0.125
0.340	0.134
0.360	0.145
0.400	0.174
0.420	0.199
0.500	0.253
0.600	0.352
0.700	0.398
0.800	0.347
0.897	0.451
1.122	0.634
1.301	0.728
1.499	0.757
1.696	0.773
1.895	0.780
2.095	0.793
2.293	0.802
2.491	0.821
2.690	0.853
CURVE 37 T = 293.	
0.220	0.429
0.240	0.438
0.260	0.407
0.280	0.381
0.300	0.349
0.320	0.344
0.340	0.322
0.360	0.318
0.420	0.354
0.500	0.373
0.600	0.367
0.700	0.429
0.800	0.418
0.896	0.464
1.094	0.631
1.298	0.700
1.496	0.745

* NOT SHOWN IN FIGURE.

TABLE 1-8. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ
CURVE 37 (CONT.)	
1.696	0.755
1.895	0.771
2.093	0.771
2.289	0.784
2.488	0.784
2.690	0.812
CURVE 38	
T = 293.	
0.220	0.246
0.240	0.295
0.260	0.338
0.285	0.366
0.305	0.401
0.325	0.439
0.340	0.465
0.360	0.493
0.420	0.542
0.500	0.631
0.600	0.679
0.700	0.679
0.800	0.687
0.200	0.249
0.311	0.403
0.401	0.546
0.500	0.645
0.601	0.692
0.699	0.685
0.796	0.691
0.895	0.701
1.098	0.802
1.299	0.826
1.500	0.850
1.697	0.860
1.902	0.862
2.101	0.873
2.298	0.870
2.498	0.861
2.697	0.812

λ	ρ
CURVE 39	
T = 293.	
0.220	0.263
0.240	0.306
0.260	0.353
0.280	0.371
0.300	0.409
0.320	0.443
0.340	0.482
0.360	0.507
0.420	0.554
0.500	0.652
0.600	0.694
0.704	0.694
0.800	0.695
0.202	0.264
0.303	0.415
0.403	0.560
0.500	0.659
0.603	0.702
0.720	0.703
0.804	0.703
0.899	0.719
1.099	0.810
1.299	0.841
1.499	0.862
1.697	0.870
1.900	0.872
2.121	0.888
2.303	0.884
2.527	0.875
2.725	0.824
CURVE 40	
T = 293.	
0.220	0.291
0.240	0.332
0.260	0.369
0.280	0.404
0.300	0.428

λ	ρ
CURVE 40 (CONT.)	
0.320	0.470
0.340	0.504
0.360	0.528
0.420	0.565
0.500	0.666
0.600	0.705
0.700	0.698
0.800	0.707
0.202	0.295
0.299	0.434
0.400	0.573
0.498	0.674
0.599	0.714
0.695	0.708
0.801	0.715
0.898	0.731
1.100	0.825
1.300	0.855
1.499	0.872
1.697	0.882
1.896	0.882
2.096	0.887
2.298	0.894
2.501	0.879
2.694	0.828
CURVE 41	
T = 293.	
0.220	0.320
0.240	0.362
0.260	0.398
0.280	0.429
0.300	0.458
0.320	0.489
0.340	0.518
0.360	0.550
0.420	0.590
0.500	0.697
0.600	0.719

λ	ρ
CURVE 41 (CONT.)	
0.700	0.746
0.800	0.755
0.200	0.323
0.301	0.464
0.399	0.592
0.497	0.703
0.598	0.726
0.699	0.752
0.798	0.763
0.899	0.781
1.099	0.863
1.299	0.895
1.498	0.905
1.699	0.906
1.898	0.906
2.096	0.906
2.298	0.909
2.503	0.898
2.694	0.858
CURVE 42	
T = 293.	
2.53	0.9150
2.92	0.9283
3.36	0.9391
3.63	0.9449
4.03	0.9495
4.48	0.9561
5.02	0.9609
7.16	0.9671
8.38	0.9710
9.10	0.9734
9.98	0.9731
11.13	0.9735
12.54	0.9754
14.31	0.9771
16.66	0.9810
19.11	0.9805
20.00	0.9833

λ	ρ
CURVE 43	
T = 293.	
2.00	0.928
2.06	0.818
2.10	0.963
2.17	0.874
2.23	0.966
2.28	0.882
2.30	0.957
2.34	0.896
2.36	0.915
2.43	0.931
2.47	0.968
2.51	0.952
2.58	0.975
2.66	0.928
2.70	0.945
2.78	0.961
2.83	0.948
3.00	0.940
3.08	0.958
3.26	0.947
3.33	0.964
3.55	0.952
3.83	0.970
3.97	0.962
4.03	0.975
4.19	0.968
4.28	0.979
4.37	0.979
4.49	0.968
4.59	0.968
4.71	0.976
4.87	0.970
5.05	0.980
6.00	0.980
6.99	0.984
7.63	0.991
7.98	0.984
8.24	0.994
8.41	0.987

λ	ρ
CURVE 43 (CONT.)	
8.88	0.991
9.02	0.988
9.62	0.988
9.81	0.993
10.00	0.989
12.00	0.988
12.22	0.992
14.67	0.992
CURVE 44	
T = 293.	
2.8	0.96
3.8	0.96
5.0	0.96
10.6	0.95
CURVE 45	
T = 293.	
2.8	0.96
3.8	0.96
5.0	0.96
10.6	0.95
CURVE 46	
T = 293.	
2.8	0.94
3.8	0.95
5.0	0.96
10.6	0.96
CURVE 47	
T = 293.	
0.40	0.468
0.44	0.460
0.47	0.471
0.56	0.471

TABLE 1-8. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ
CURVE 47 (CONT.)		CURVE 47 (CONT.)	
0.58	0.480	12.63	0.891
0.68	0.480	13.00	0.900
0.78	0.492	14.90	0.900
0.87	0.492	15.19	0.891
0.91	0.511	17.29	0.891
0.93	0.512	17.57	0.900
1.00	0.541	25.00	0.899
1.15	0.616		
1.76	0.715		
2.14	0.752		
2.37	0.761		
2.60	0.752		
2.85	0.726		
3.07	0.771		
3.28	0.786		
3.60	0.801		
3.73	0.817		
3.89	0.832		
4.11	0.832		
4.29	0.839		
4.31	0.851		
4.61	0.851		
5.10	0.870		
5.65	0.853		
5.90	0.822		
6.35	0.822		
6.60	0.852		
6.88	0.844		
7.40	0.861		
7.83	0.862		
8.07	0.871		
8.40	0.871		
8.64	0.864		
8.99	0.871		
9.57	0.871		
9.87	0.882		
10.37	0.882		
10.57	0.892		
12.12	0.892		
12.40	0.900		

e. Normal Spectral Reflectance (Temperature Dependence)

There are no experimental data available. The provisional values listed in Table 1-9 and shown in Figure 1-15 are from the relationship discussed in subsection 4.20 and based on Eq. (2.5-5) for highly polished alclad Aluminum Alloy 2024 assuming that aluminum is the cladding material for wavelengths of 2.8, 3.8, 5.0, and 10.6 μm. These values are believed accurate to ±20%.

TABLE 1-9. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

T	ρ	T	ρ	T	ρ	T	ρ
HIGHLY POLISHED ALCLAD λ = 2.8		HIGHLY POLISHED ALCLAD λ = 3.8		HIGHLY POLISHED ALCLAD λ = 5.0		HIGHLY POLISHED ALCLAD λ = 10.6	
250.0	0.946	250.0	0.962	250.0	0.970	250.0	0.981
293.0	0.943	293.0	0.959	293.0	0.967	293.0	0.979
300.0	0.943	300.0	0.959	300.0	0.967	300.0	0.979
350.0	0.940	350.0	0.956	350.0	0.964	350.0	0.977
400.0	0.938	400.0	0.954	400.0	0.962	400.0	0.976
450.0	0.937	450.0	0.952	450.0	0.960	450.0	0.974
500.0	0.935	500.0	0.950	500.0	0.959	500.0	0.973
550.0	0.934	550.0	0.948	550.0	0.957	550.0	0.972
600.0	0.933	600.0	0.947	600.0	0.956	600.0	0.971
650.0	0.932	650.0	0.945	650.0	0.954	650.0	0.970
700.0	0.932	700.0	0.944	700.0	0.953	700.0	0.969
750.0	0.931	750.0	0.943	750.0	0.952	750.0	0.968

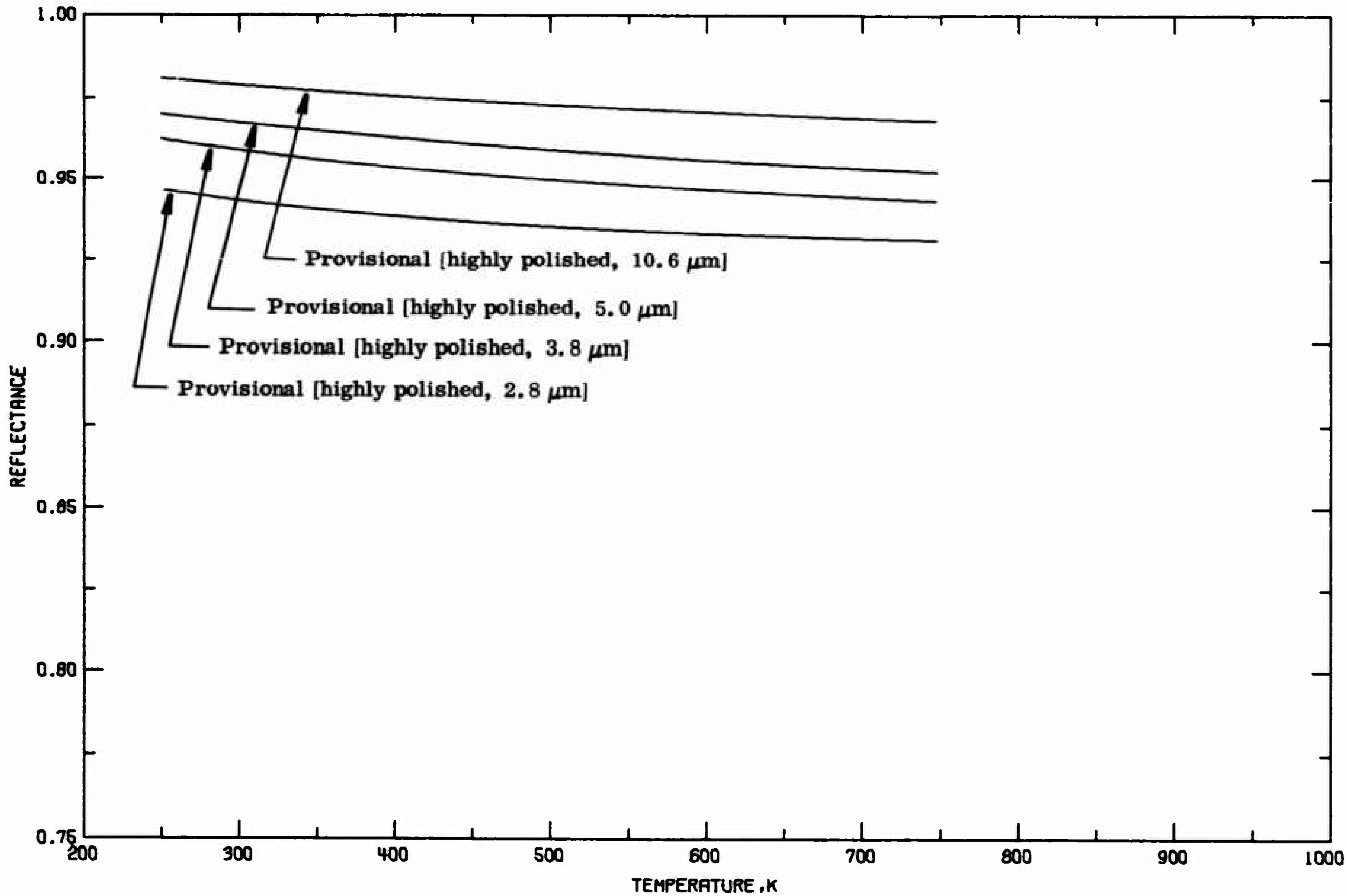


FIGURE 1-15. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF ALCLAD ALUMINUM ALLOY 2024 (TEMPERATURE DEPENDENCE).

f. Angular Spectral Reflectance (Wavelength Dependence)

There are 191 sets of experimental data for various surface conditions of Aluminum Alloy 2024. Of these sets 111 are for grooved surfaces by Zipin [T39074] which are included in the report as additional information. The analysis includes two types of Aluminum Alloy 2024, anodized and alodined.

There are seven sets of experimental data for anodized Aluminum Alloy 2024 and four sets of experimental data for alodined Aluminum Alloy 2024, both with the angle of incidence equal to 15°. For the alodined Aluminum Alloy 2024, there is one set of experimental data available for an incidence angle of 45°.

(1) Anodized Aluminum Alloy 2024

The experimental data sets are shown in Figure 1-17 and listed in Table 1-12. The provisional values for temperature 293 K are given in Table 1-10 and shown in Figure 1-16 and are considered accurate to within ±15% over the entire wavelength range at 293 K. These values show the absorption peaks near wavelengths 0.8, 2.9, 6.0, 9.9, and 11.0 μm and these values are considerably lower than those for polished alclad Aluminum Alloy 2024 and alodined Aluminum Alloy 2024 for wavelengths above 5.5 μm. These provisional values apply only to the surface conditions cited in references, see Section 4.1c.

(2) Alodined Aluminum Alloy 2024

The experimental data sets are shown in Figure 1-19 and listed in Table 1-12 for an incidence angle of 15°. The provisional values at 293 K, shown in Figure 1-18 and listed in Table 1-10 are primarily from the investigations of Grimm and Fannin [A00001]. These are considered accurate to within ±15% over the entire wavelength range. These values show absorption peaks near wavelengths 3.1 and 4.8 μm. The experimental data set is shown in Figure 1-21 and listed in Table 1-12 for an incidence angle of 45°. The provisional values of angular spectral reflectance from the investigation of Grimm and Fannin [A00001] are accurate to within ±20% over the entire reported wavelength range. These values also show absorption peaks near wavelengths 3.1 and 4.8 μm. The provisional values apply only to the surface conditions cited in references, see Section 4.1c.

TABLE 1-10. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

SULFURIC ACID ANODIZED, θ=15°, T = 293

λ	ρ
0.30	0.260
0.35	0.360
0.40	0.450
0.50	0.518
0.60	0.526
0.70	0.525
0.80	0.519
0.83	0.518
0.90	0.566
1.00	0.620
1.20	0.680
1.40	0.708
1.60	0.726
1.80	0.732
2.00	0.721
2.20	0.699
2.40	0.659
2.60	0.578
2.80	0.221
2.85	0.193
2.90	0.190
2.95	0.192
3.00	0.203
3.20	0.323
3.40	0.408
3.60	0.474
3.80	0.516
4.00	0.546
4.20	0.572
4.40	0.590
4.60	0.604
4.80	0.613
5.00	0.616
5.20	0.618
5.40	0.610
5.60	0.594
5.80	0.558
5.90	0.524
6.00	0.516

SULFURIC ACID ANODIZED, θ=15°, T = 293 (CONT.)

λ	ρ
6.10	0.516
6.20	0.527
6.40	0.590
6.60	0.602
6.80	0.595
7.00	0.574
7.20	0.486
7.40	0.360
7.60	0.260
7.80	0.180
8.00	0.125
8.20	0.082
8.40	0.058
8.60	0.051
8.80	0.053
9.00	0.060
9.20	0.080
9.40	0.107
9.60	0.136
9.80	0.145
10.00	0.136
10.20	0.100
10.40	0.065
10.60	0.040
10.80	0.028
11.00	0.025
11.20	0.037
11.40	0.045
11.60	0.051
11.80	0.057
12.00	0.062
12.50	0.072
13.00	0.080
13.50	0.085
14.00	0.091
14.50	0.095
15.00	0.098

CHROMATE ALODINED, θ=15°, T = 293

λ	ρ
2.34	0.483
2.50	0.469
2.80	0.396
3.00	0.323
3.05	0.315
3.10	0.311
3.15	0.312
3.20	0.318
3.25	0.327
3.30	0.345
3.50	0.411
3.70	0.472
3.80	0.492
4.00	0.520
4.20	0.542
4.50	0.569
4.56	0.574
4.61	0.573
4.70	0.539
4.74	0.522
4.77	0.519
4.81	0.528
4.87	0.560
4.93	0.595
4.95	0.603
5.00	0.606
5.50	0.638
6.00	0.666
6.50	0.692
7.00	0.715
7.50	0.737
8.00	0.756
8.5	0.773
9.0	0.790
9.5	0.805
10.0	0.818
10.6	0.833
11.0	0.842
11.5	0.850

CHROMATE ALODINED, θ=15°, T = 293 (CONT.)

λ	ρ
12.0	0.858
12.5	0.865
13.0	0.871
13.5	0.877
14.0	0.882
14.5	0.887
15.0	0.891

CHROMATE ALODINED, θ=45°, T = 293

λ	ρ
2.00	0.760
2.20	0.742
2.40	0.712
2.60	0.642
2.80	0.448
3.00	0.380
3.10	0.382
3.20	0.394
3.40	0.450
3.60	0.530
3.80	0.592
4.00	0.634
4.20	0.662
4.40	0.680
4.50	0.684
4.60	0.680
4.70	0.600
4.72	0.588
4.76	0.586
4.80	0.538
4.90	0.680
5.00	0.702
5.20	0.720
5.40	0.730
5.60	0.740
5.80	0.748
6.00	0.754
7.00	0.780
8.00	0.800
9.00	0.819
10.00	0.836
10.60	0.844
11.00	0.850
12.00	0.864
13.00	0.873
14.00	0.884

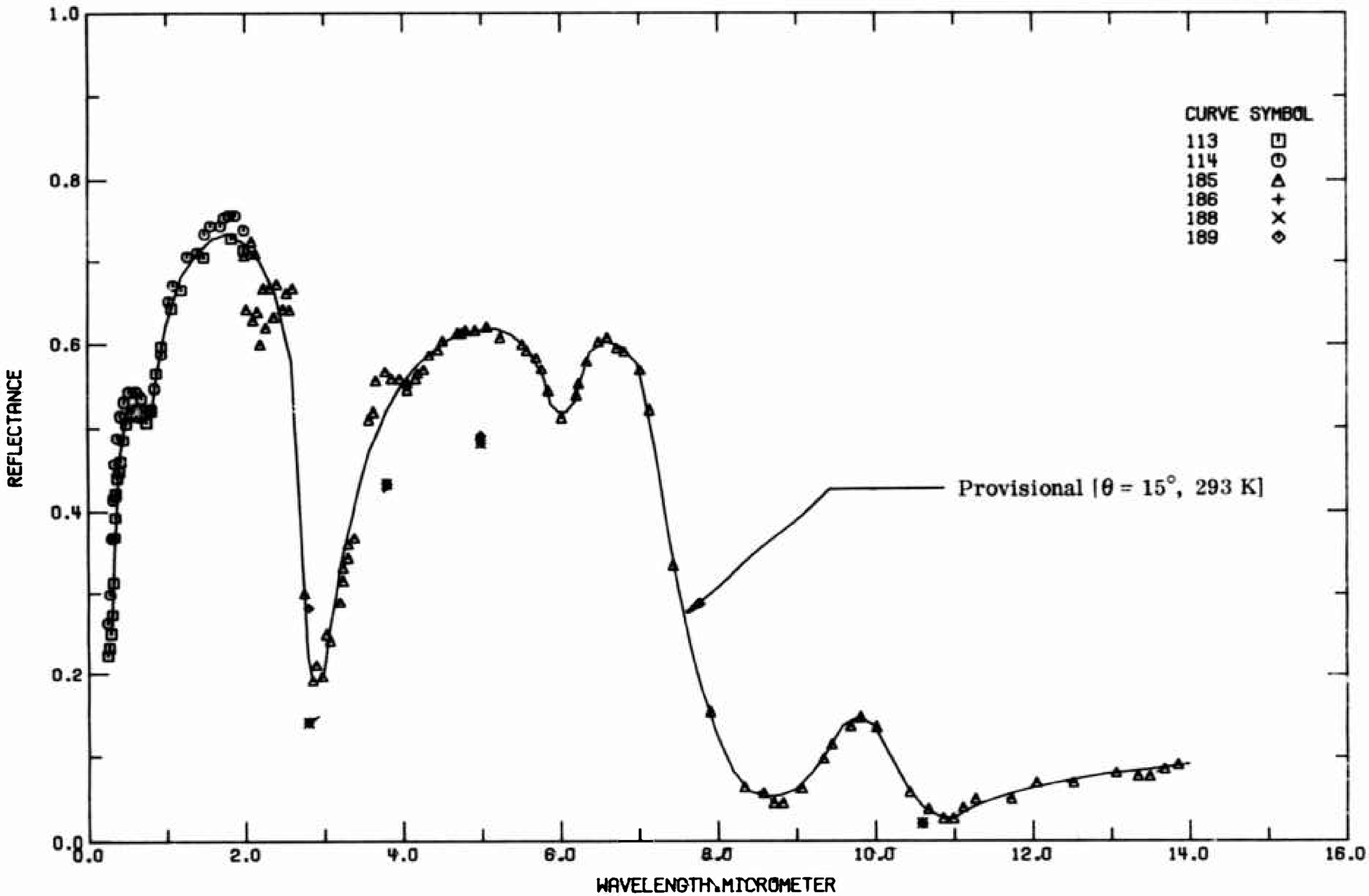


FIGURE 1-16. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF ANODIZED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

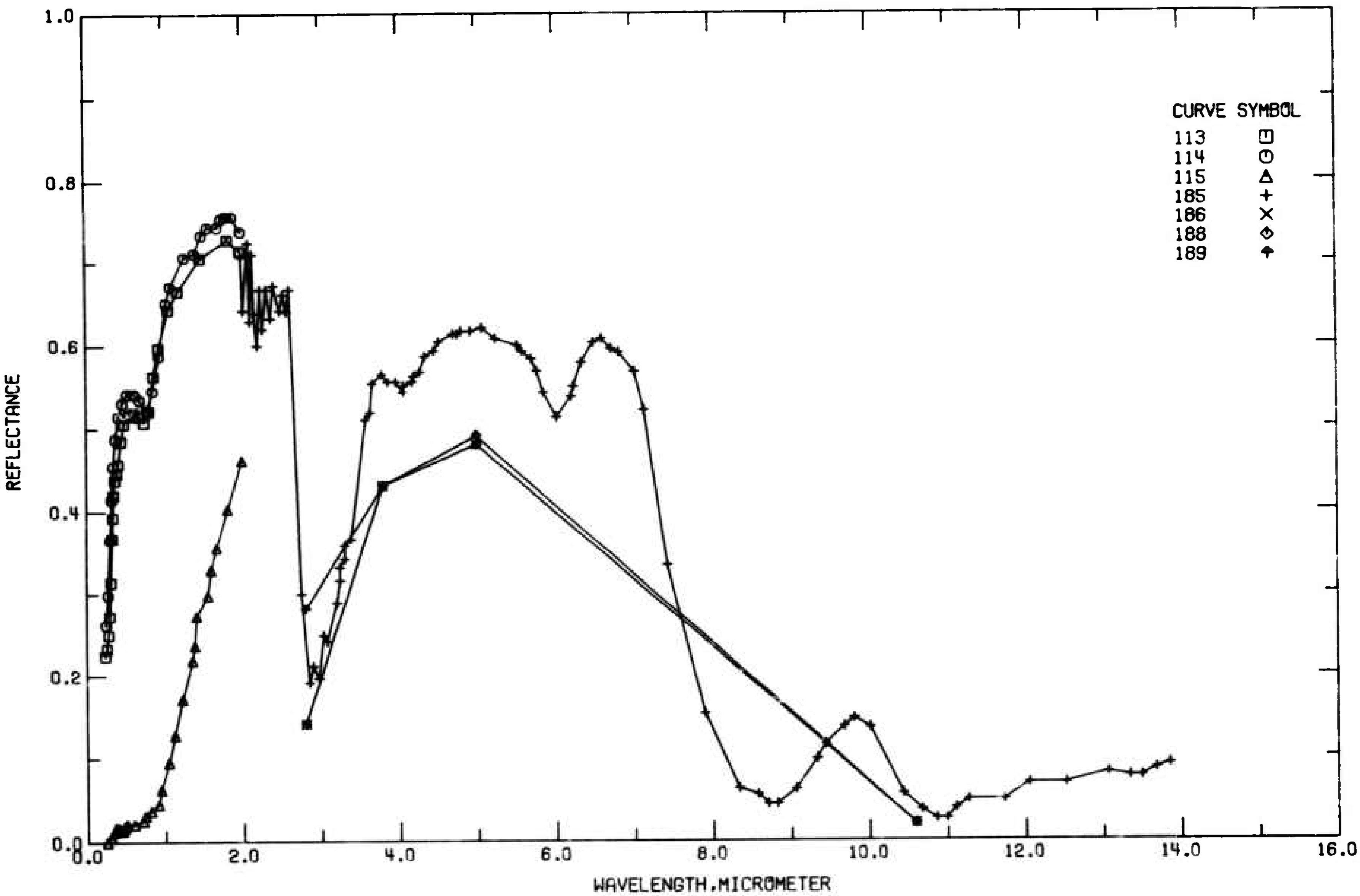


FIGURE 1 17. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ANODIZED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

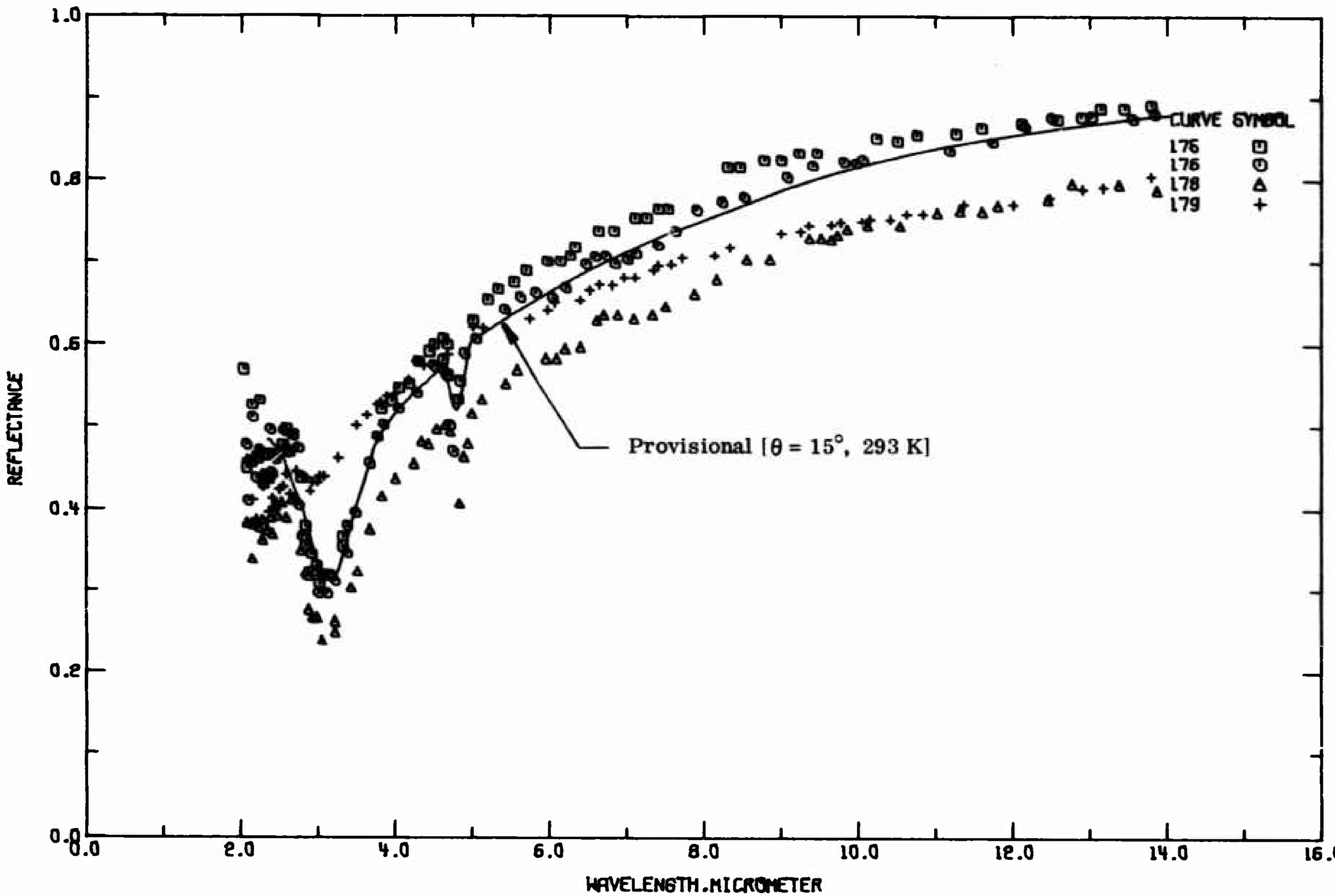


FIGURE 1-18. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF ALODINED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

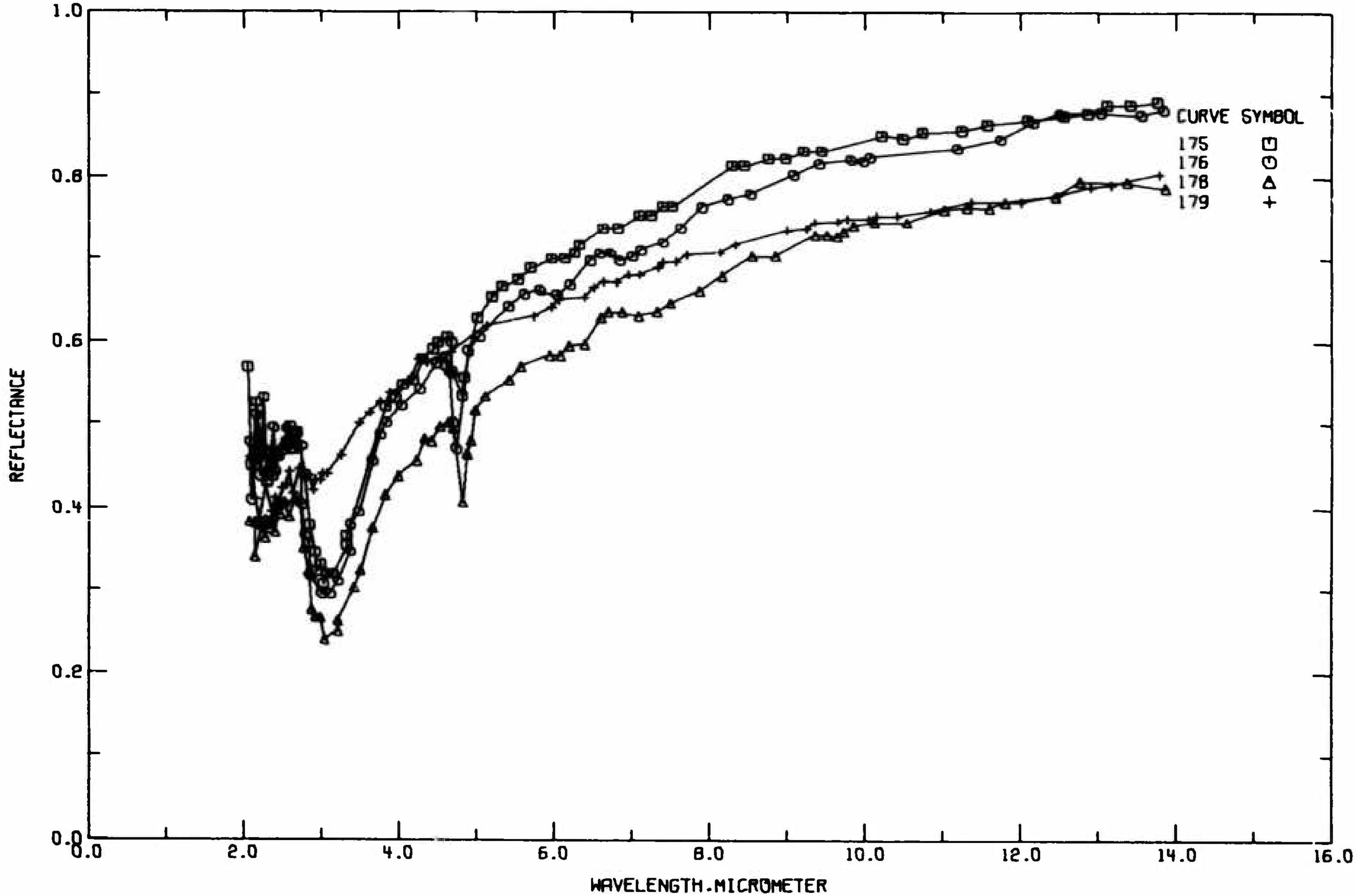


FIGURE 1-19. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALODINED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

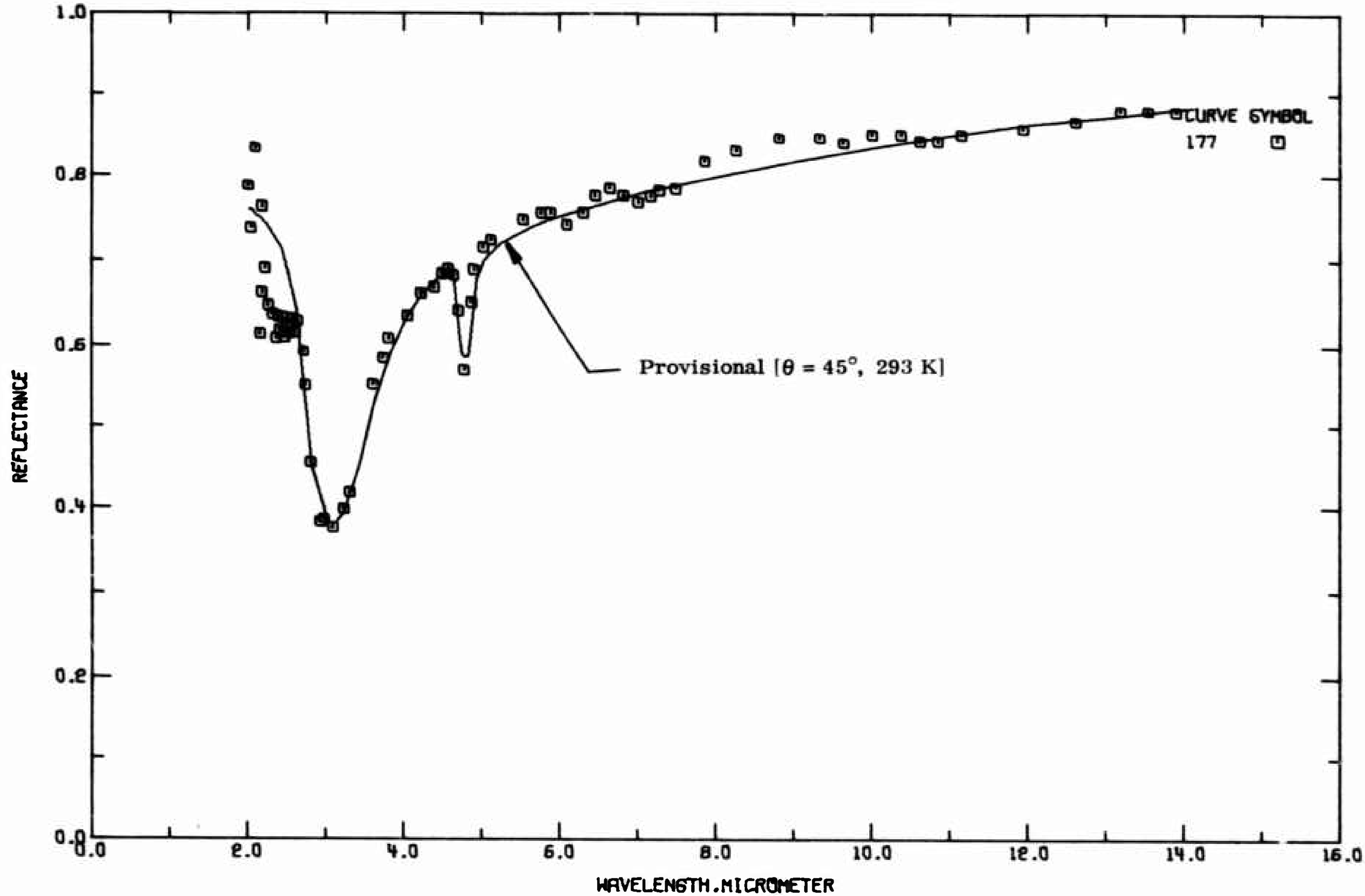


FIGURE 1-20. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF ALODINED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

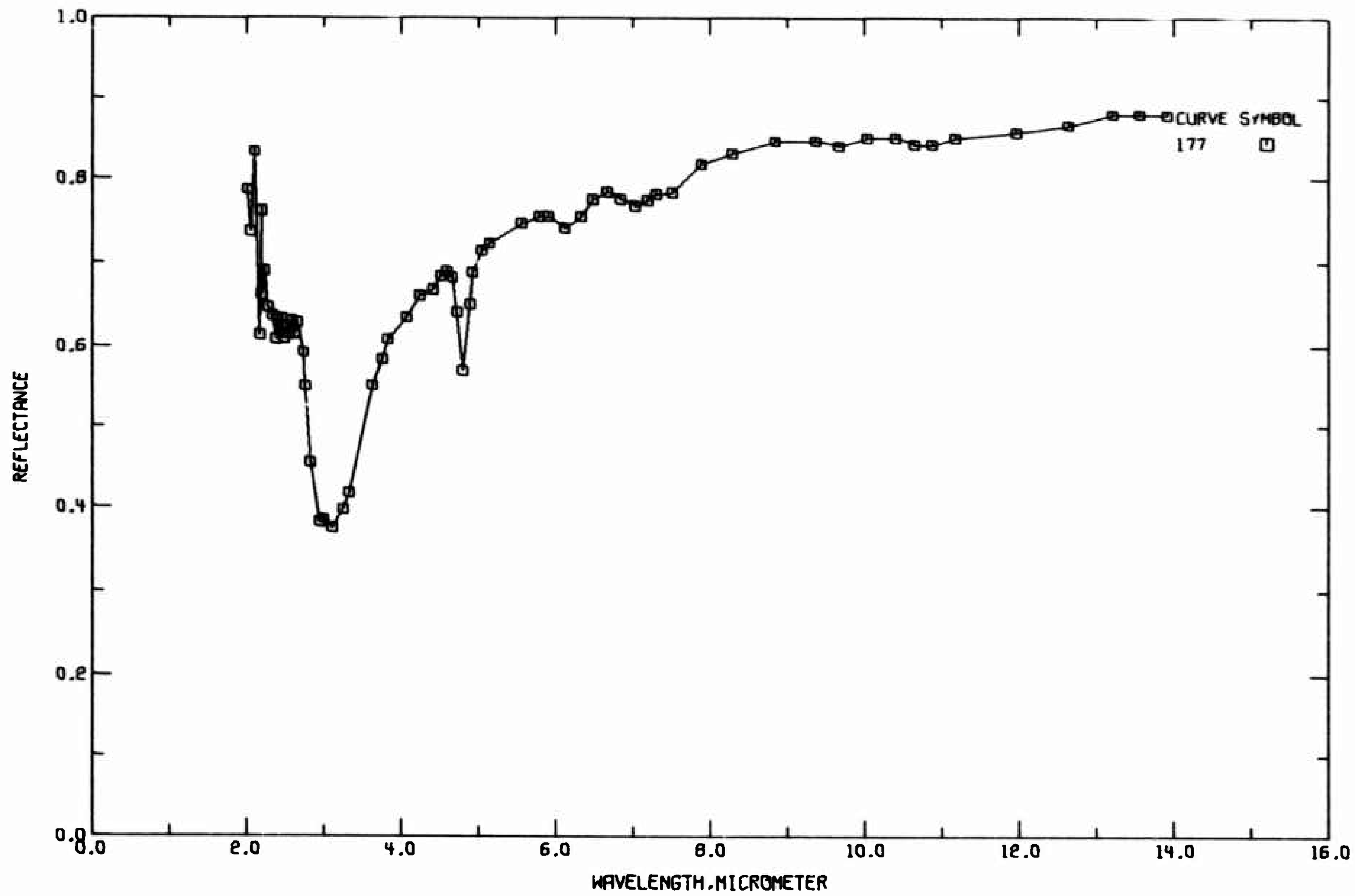


FIGURE 1-21. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALODINED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

TABLE 1-11. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T36486	Aronson, J.R. and McLinden, H.G.	1964	20.0-99.0	8.5 ± 1	Aluminum Alloy 2024	Samples were 0.02 meter disks of a few mm thickness; measurement made by Perkin-Elmer Model 201-C spectrometer while temperature measured by carbon composition resistor; reflectance measured relative to Aluminum 2024 at room temperature; smooth values extracted from figure; θ=45°, reported error ± 5%.
2	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 3	Specimen was 15/16" x 1" x 1" with symmetric V-grooves cut into one 15/16" x 1" face; grooved surfaces made for this study with ruling machine of type used by Bausch and Lomb, Inc.; specifications of grooved profiles and angle as reported by manufacturer, valley to valley distance (w), 50 μm, peak to valley height (h), 25.4 μm, and angle between faces, 89°9'; source used is G.E. 30A/T20/4 tungsten ribbon strip lamp enclosed in H_2O cooled shield, monochromator used was Perkin-Elmer Model 83, detectors used were RCA 1P28 photomultiplier tube for visible (0.2-0.7 μ) and Perkin-Elmer lead sulfide photoconducting cell for near infrared (0.4-2.8 μ); incident beam and viewing path was perpendicular to groove; angle θ' said to be negative if measured in same direction from normal as θ; θ' uncertainty ± 1°; reference was standard mirror; specimen appeared "bright and shining" to eye; measured temperature specified as room temperature, 293 K assigned; θ=75°, θ'=-15.25°, reported error ± 0.05%.
3	T39074	Zipin, R.B.	1965	0.5, 1.5	293	Aluminum Alloy 2024T-4, Sample 3	The above specimen except θ=15°, θ'=-74.5°.
4	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 3	The above specimen except θ=75°, θ'=-15.5°.
5	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 4	Similar to the above specimen except w = 25 μm, h = 12.7 μm, the angle of the V-groove is 89°9'.
6	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 4	The above specimen except θ=15°, θ'=-74.5°.
7	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	Similar to the above specimen except w = 16.67 μm, h = 2.19 μm, the angle of the V-groove is 150°30', incident and observation angle as specified, different wavelengths; θ'=45°.
8	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=38°.
9	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 7	Similar to the above specimen except w = 83.33 μm, h = 24.4 μm, the angle of the V-groove is 119°15', θ=75°, θ'=15°.
10	T39074	Zipin, R.B.	1965	0.5, 1.5	293	Aluminum Alloy 2024T-4, Sample 7	The above specimen except θ=60°, θ'=0°.
11	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 7	The above specimen except θ=45°, θ'=13°.
12	T39074	Zipin, R.B.	1965	0.5, 1.5	293	Aluminum Alloy 2024T-4, Sample 7	The above specimen except θ=30°, θ'=27°.
13	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 7	The above specimen except θ=15°, θ'=74.5°.
14	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 7	The above specimen except θ'=42.5°.

TABLE 1-11. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
15	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 7	The above specimen except θ=75°, θ'=14.5°.
16	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 7	The above specimen except θ=45°, θ'=14°.
17	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 7	The above specimen except θ=15°, θ'=74°.
18	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 7	The above specimen except θ'=42°.
19	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 8	Similar to the above specimen except w = 41.67 μm, h = 12.2 μm, the angle of the V-groove is 119°20'; θ=75°, θ'=15°.
20	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 8	The above specimen except θ=60°, θ'=0°.
21	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 8	The above specimen except θ=45°, θ'=14°.
22	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 8	The above specimen except θ=30°, θ'=28°.
23	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 8	The above specimen except θ=15°, θ'=74.5°.
24	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 8	The above specimen except θ'=43°.
25	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 8	The above specimen except θ=75°, θ'=14.5°.
26	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 8	The above specimen except θ=45°, θ'=15.5°.
27	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 8	The above specimen except θ=15°, θ'=73°.
28	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 8	The above specimen except θ'=42°.
29	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 9	Similar to the above specimen except w = 16.67 μm, h = 4.9 μm, the angle of the V-groove is 119°6'; θ=60°, θ'=0.5°.
30	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 9	The above specimen except θ=45°, θ'=16.5°.
31	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 9	The above specimen except θ=30°, θ'=32.5°.
32	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 9	The above specimen except θ=15°, θ'=72.5°.
33	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 9	The above specimen except θ'=49.5°.
34	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 11	Similar to the above specimen except w = 200 μm, h = 26.5 μm, the angle of the V-groove is 150°16'; θ=75°, θ'=45°.

TABLE 1-11. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
35	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 11	The above specimen except θ=60°, θ'=60°.
36	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 11	The above specimen except θ'=30°.
37	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 11	The above specimen except θ=45°, θ'=74.5°.
38	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 11	The above specimen except θ'=15°.
39	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 11	The above specimen except θ=30°, θ'=60°.
40	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 11	The above specimen except θ=15°, θ'=45°.
41	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 12	Similar to the above specimen except w = 100 μm, h = 13.25 μm, the angle of the V-groove is 150°17'; θ=75°, θ'=45°.
42	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 12	The above specimen except θ=60°, θ'=60°.
43	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 12	The above specimen except θ'=30°.
44	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 12	The above specimen except θ=45°, θ'=74.5°.
45	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 12	The above specimen except θ'=15°.
46	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 12	The above specimen except θ=30°, θ'=60°.
47	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 12	The above specimen except θ=15°, θ'=45°.
48	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	Similar to the above specimen except w = 41.67 μm, h = 5.48 μm, the angle of the V-groove is 150°29'; θ'=44.5°.
49	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ=75°, θ'=45.75°.
50	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ=60°, θ'=60°.
51	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=31°.
52	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ=45°, θ'=75°.
53	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=16°.
54	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ=30°, θ'=60°.

TABLE 1-11. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
55	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ=15°, θ'=45°.
56	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ=75°, θ'=59°.
57	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=55°.
58	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=52°.
59	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=48.5°.
60	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=45.5°.
61	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=42.5°.
62	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=39.5°.
63	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=37.5°.
64	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=34.5°.
65	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ=60°, θ'=64.5°.
66	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=56.5°.
67	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=53°.
68	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=50°.
69	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=46.5°.
70	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=41°.
71	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=35.5°.
72	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=33°.
73	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=30.5°.
74	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 13	The above specimen except θ'=28.5°.

TABLE 1-11. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
75	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 14	Similar to the above specimen except w = 16.67 μm, h = 2.19 μm, the angle of the V-groove is 150°30'; θ'=23.5°.
76	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=66.5°.
77	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=62.5°.
78	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=58.5°.
79	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=55.5°.
80	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=53.5°.
81	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=50.5°.
82	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=43°.
83	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=39.5°.
84	T39074	Zipin, R.B.	1965	0.5,1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=36°.
85	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=32.5°.
86	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=30.5°.
87	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=28.25°.
88	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ=75°, θ'=60.5°.
89	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=51.25°.
90	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=43.5°.
91	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=36.5°.
92	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ=60°, θ'=73.5°.
93	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=59.5°.
94	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except θ'=50°.

TABLE 1-11. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
95	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=30°$.
96	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=24°$.
97	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta=45°$, $\theta'=75°$.
98	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=63°$.
99	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=52.5°$.
100	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=38°$.
101	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=31°$.
102	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=25.8°$.
103	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=20°$.
104	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=14.5°$.
105	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=9°$.
106	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta=30°$, $\theta'=68.5°$.
107	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=59°$.
108	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=51°$.
109	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta'=42.5°$.
110	T39074	Zipin, R.B.	1965	1.5	293	Aluminum Alloy 2024T-4, Sample 14	The above specimen except $\theta=15°$, $\theta'=52°$.
111	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 5	Similar to the above specimen except w = 10 μm, h = 5 μm, the angle of the V-groove is 90°; grooves made by burnishing with weighted diamond; specimen did not appear "bright and shining" to eye; $\theta=75°$, $\theta'=-20°$, reported error ±0.05%.
112	T39074	Zipin, R.B.	1965	0.5	293	Aluminum Alloy 2024T-4, Sample 5	The above specimen except $\theta=15°$, $\theta'=-74.5°$.
113	T43493	Bevans, J.T., Brown, G.L., Luedke, E.E., Millu, W.D., Nelson, K.E., and Russell, D.A.	1962	0.25-2.0	303		Sample materials prepared by Anadite Corp., South Gate, Calif.; sample discs were 19 mm in diameter; soft sulfuric acid anodize; 30 μm thick irradiation treatment; source used was GE B-H6 Mercury Arc Lamp at level of 5.5×10^3 Watt/meter^2, spectral reflectances measured with either integrating sphere reflectometer or Beckman DK-2A modified reflectometer; data extracted from smooth curve; temperature not monitored for each sample, range 294-311, average temperature of 303 used; $\theta=15°$, $\omega'=2\pi$.

TABLE 1-11. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
114	T43493	Bevans, J.T., Brown, G.L., Luedke, E.E., Millue, W.D., Nelson, K.E., and Russell, D.A.	1962	0.25-2.0	303		Similar to the above specimen except measurements made after exposure period of 2.2 hr at atm pressure.
115	T43493	Bevans, J.T., et al.	1962	0.25-2.0	303		Similar to the above specimen except measurements made after exposure period of 96 hr at pressure of 10^{-6} Torr.
116	T29563	Eberhart, R.C.	1960	1.2,1.8	293	Aluminum 24ST, Polished	Specimen 2.22 cm discs, 0.16 to 0.32 cm thick; sample surface prepared by standard metallographic techniques, average horizontal peak to peak distance is 30 μm, groove depth (average displacement from mean surface line) is 0.40 μm, integrating sphere used with PbS detector; reference standard MgO; data extracted from figure; measurement temperature not given explicitly, 293 K assigned; θ=20°, $\omega'=2\pi$.
117	T29563	Eberhart, R.C.	1960	1.2,1.8	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=30°.
118	T29563	Eberhart, R.C.	1960	1.2,1.8	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=40°.
119	T29563	Eberhart, R.C.	1960	1.2,1.8	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=50°.
120	T29563	Eberhart, R.C.	1960	1.2,1.8	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=60°.
121	T29563	Eberhart, R.C.	1960	1.2,1.8	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=70°.
122	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except data extracted from smooth curve; θ=15°.
123	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=20°.
124	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=25°.
125	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=30°.
126	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=35°.
127	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=40°.
128	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=45°.
129	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=50°.
130	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=55°.

TABLE 1-11. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
131	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=60°.
132	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=65°.
133	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Similar to the above specimen except θ=70°.
134	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except average horizontal peak to peak distance, 7 μm, groove depth, 3.18 μm; sample surface prepared with sandpaper; data extracted from smooth curve; θ=15°.
135	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=20°.
136	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=25°.
137	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=30°.
138	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=35°.
139	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=40°.
140	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=45°.
141	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=50°.
142	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=55°.
143	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=60°.
144	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=65°.
145	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=70°.
146	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=75°.
147	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 1	Similar to the above specimen except θ=80°.
148	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except average horizontal peak to peak distance, 10 μm, groove depth, 4.52 μm; sample surface prepared with sandpaper; θ=15°.
149	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=20°.
150	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=25°.

TABLE 1-11. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
151	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=30°.
152	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=35°.
153	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=40°.
154	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=45°.
155	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=50°.
156	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=55°.
157	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=60°.
158	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=65°.
159	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=70°.
160	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=75°.
161	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Grade 2	Similar to the above specimen except θ=80°.
162	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Polished; Beckman DK2 spectrometer integrating sphere used for measurement; MgO reference standard; data extracted from figure; measurement temperature not given explicitly, 293 K assigned; θ=20°, ω'=2π.
163	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except θ=30°.
164	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except θ=40°.
165	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except θ=50°.
166	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except θ=60°.
167	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except θ=70°.
168	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Roughened sample; surface roughened with sandpaper, scratches parallel; course structure - peak to peak depth 6.35 μm, spacing, 34 μm, fine structure - peak to peak depth, 1 μm; Beckman DK2 spectrometer integrating sphere used for measurement; MgO reference standard; data extracted from figure; measuremente temperature not given explicitly, 293 K assigned; θ=20°, ω'=2π.

TABLE 1-11. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
169	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except θ=30°.
170	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except θ=40°.
171	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except θ=50°.
172	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except θ=60°.
173	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except θ=70°.
174	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Similar to the above specimen except θ=80°.
175	A00001	Grimm, F.C. and Fannin, E.R.	1972	2-14.7	293	2024-T81 Alclad, Sample No. A-1	Specimen brush-alodined; sample thickness 101.6 x 10^{-3} cm; samples prepared by Organic Chemistry Laboratory of Dept. 256; measurements made with a Dunn Associates ellipsoidal mirror reflectometer; measurement temperature specified as ambient temperature, 293 K assigned; data extracted from smooth curve; relative reflectance reported, multiplied by 0.95 to convert to absolute (gold reference standard used); θ=15°, ω'=2π; chromate conversion coating.
176	A00001	Grimm, F.C. and Fannin, E.R.	1972	2-14.7	293	2024-T81 Alclad, Sample No. A-1	The above specimen; reported values different from the values of above specimen for unknown reason.
177	A00001	Grimm, F.C. and Fannin, E.R.	1972	2-14.7	293	2024-T81 Alclad, Sample No. A-1	The above specimen except θ=45°.
178	A00001	Grimm, F.C. and Fannin, E.R.	1972	2-14.7	293	2024-T81 Alclad, Sample No. A-1	The above specimen; reported values different from the values of above specimen for unknown reason; θ=15°.
179	A00001	Grimm, F.C. and Fannin, E.R.	1972	2-14.7	293	2024-T81 Alclad, Sample No. A-1	The above specimen except sample heat treated by heating to 644 K for 1 hr in air.
180	A00001	Grimm, F.C. and Fannin, E.R.	1972	2-14.7	293	2024-T81 Alclad, Sample No. B-1	Polished; sample thickness 99 x 10^{-3} cm; samples prepared by Organic Chemistry Laboratory of Dept. 256; measurements made with a Dunn Associates ellipsoidal mirror reflectometer; measurement temperature specified as ambient temperature, 293 K assigned; data extracted from smooth curve; relative reflectance reported multiplied by 0.95 to convert to absolute (gold reference standard used); θ=15°, ω'=2π.
181	A00001	Grimm, F.C. and Fannin, E.R.	1972	2.8-10.6	293	2024-T81 Alclad, Sample No. B-1	The above specimen; reported values different from the values of above specimen for unknown reason; data extracted from table.
182	A00001	Grimm, F.C. and Fannin, E.R.	1972	2.8-10.6	293	2024-T81 Alclad, Sample No. B-1	The above specimen except θ=45°.
183	A00001	Grimm, F.C. and Fannin, E.R.	1972	2.8-10.6	293	2024-T81 Alclad, Sample No. B-1	The above specimen; reported values different from the values of above specimen for unknown reason; data extracted from table; θ=15°.
184	A00001	Grimm, F.C. and Fannin, E.R.	1972	2.8-10.6	293	2024-T81 Alclad, Sample No. B-1	The above specimen except sample heat treated by heating to 644 K for 1 hr in air.

TABLE 1-11. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
185	A00001	Grimm, F.C. and Fannin, E.R.	1972	2-14.7	293	2024-T851 Al, Sample No. C-1	Anodized with sulfuric acid; sample thickness ~0.254 cm; samples prepared by Organic Chemistry Laboratory of Dept. 256; measurements made with a Dunn Associate ellipsoidal mirror reflectometer; measurement temperature specified as ambient temperature, 293 K assigned; data extracted from smooth curve; relative reflectance reported multiplied by 0.95 to convert to absolute (gold reference standard used); θ=15°, ω'=2π.
186	A00001	Grimm, F.C. and Fannin, E.R.	1972	2.8-10.6	293	2024-T851 Al, Sample No. C-1	The above specimen; reported values different from the values of above specimen for unknown reason.
187	A00001	Grimm, F.C. and Fannin, E.R.	1972	2.8-10.6	293	2024-T851 Al, Sample No. C-1	The above specimen except θ=45°.
188	A00001	Grimm, F.C. and Fannin, E.R.	1972	2.8-10.6	293	2024-T851 Al, Sample No. C-1	The above specimen; reported values different from the values of above specimen for unknown reason; data extracted from table; θ=15°.
189	A00001	Grimm, F.C. and Fannin, E.R.	1972	2.8-10.6	293	2024-T851 Al, Sample No. C-1	The above specimen except sample heat treated by heating to 644 K for 1 hr in air.
190	T73502	Bowman, R.L., Jack, J.R., and Spisz, E.W.	1973	0.35-2.0	293	2024 T4 Aluminum	Highly polished surface; measurements made in air with Gier-Dinkle magnesium oxide coated integrating sphere reflectometer; data extracted from smooth curve; measured temperature specified as room temperature, 293 K assigned; θ=15°, ω'=2π.
191	T73502	Bowman, R.L., et al.	1973	0.35-1.1	293	2024 T4 Aluminum	Similar to the above specimen except surface had diffuse finish provided by glass-bead blasting the surface.

TABLE 1-12. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1*	
T = 8.5	
20.0	0.857
20.9	0.866
22.8	0.908
23.7	0.934
24.9	0.962
25.8	0.962
27.4	0.947
29.8	0.967
33.0	0.967
36.0	0.955
40.0	0.960
50.8	0.945
62.1	0.965
99.0	0.970
CURVE 2*	
T = 293.	
0.5	0.787
CURVE 3*	
T = 293.	
0.5	0.223
1.5	0.137
CURVE 4*	
T = 293.	
1.5	0.318
CURVE 5*	
T = 293.	
0.5	0.510
CURVE 6*	
T = 293.	
0.5	0.166
CURVE 7*	
T = 293.	
1.5	0.20
CURVE 8*	
T = 293.	
1.5	0.081
CURVE 9*	
T = 293.	
0.5	0.95
CURVE 10*	
T = 293.	
0.5	0.915
1.5	0.75
CURVE 11*	
T = 293.	
0.5	0.095
CURVE 12*	
T = 293.	
0.5	0.154
1.5	0.166
CURVE 13*	
T = 293.	
0.5	0.126
CURVE 14*	
T = 293.	
0.5	0.061
CURVE 15*	
T = 293.	
1.5	0.437
CURVE 16*	
T = 293.	
1.5	0.0676
CURVE 17*	
T = 293.	
1.5	0.136
CURVE 18*	
T = 293.	
1.5	0.056
CURVE 19*	
T = 293.	
0.5	0.355
CURVE 20*	
T = 293.	
0.5	0.47
1.5	0.46
CURVE 21*	
T = 293.	
0.5	0.065
CURVE 22*	
T = 293.	
0.5	0.124
1.5	0.088
CURVE 23*	
T = 293.	
0.5	0.16
CURVE 24*	
T = 293.	
0.5	0.049
CURVE 25*	
T = 293.	
1.5	0.254
CURVE 26*	
T = 293.	
1.5	0.0411
CURVE 27*	
T = 293.	
1.5	0.078
CURVE 28*	
T = 293.	
1.5	0.0335
CURVE 29*	
T = 293.	
0.5	0.485
CURVE 30*	
T = 293.	
0.5	0.039
CURVE 31*	
T = 293.	
0.5	0.0781
CURVE 32*	
T = 293.	
0.5	0.0995
CURVE 33*	
T = 293.	
0.5	0.265
CURVE 34*	
T = 293.	
0.5	0.024
1.5	0.675
CURVE 35*	
T = 293.	
0.5	0.164
1.5	0.13
CURVE 36*	
T = 293.	
0.5	0.568
1.5	0.625
CURVE 37*	
T = 293.	
0.5	0.315
CURVE 37 (CONT.)*	
1.5	0.295
CURVE 38*	
T = 293.	
0.5	0.455
1.5	0.53
CURVE 39*	
T = 293.	
0.5	0.380
1.5	0.380
CURVE 40*	
T = 293.	
0.5	0.405
1.5	0.440
CURVE 41*	
T = 293.	
0.5	0.875
1.5	0.576
CURVE 42*	
T = 293.	
0.5	0.14
1.5	0.077
CURVE 43*	
T = 293.	
0.5	0.655
1.5	0.56

*NOT SHOWN IN FIGURE.

TABLE 1-12. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm ; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 44*	
T = 293.	
0.5	0.280
1.5	0.211
CURVE 45*	
T = 293.	
0.5	0.615
1.5	0.505
CURVE 46*	
T = 293.	
0.5	0.300
1.5	0.312
CURVE 47*	
T = 293.	
0.5	0.325
CURVE 48*	
T = 293.	
1.5	0.357
CURVE 49*	
T = 293.	
0.5	0.738
CURVE 50*	
T = 293.	
0.5	0.09
1.5	0.06
CURVE 51*	
T = 293.	
0.5	0.55
CURVE 52*	
T = 293.	
0.5	0.235
CURVE 53*	
T = 293.	
0.5	0.465
CURVE 54*	
T = 293.	
0.5	0.305
CURVE 55*	
T = 293.	
0.5	0.337
CURVE 56*	
T = 293.	
1.5	0.645
CURVE 57*	
T = 293.	
1.5	0.0782
CURVE 58*	
T = 293.	
1.5	0.216
CURVE 59*	
T = 293.	
1.5	0.510
CURVE 60*	
T = 293.	
1.5	0.648
CURVE 61*	
T = 293.	
1.5	0.376
CURVE 62*	
T = 293.	
1.5	0.0475
CURVE 63*	
T = 293.	
1.5	0.0158
CURVE 64*	
T = 293.	
1.5	0.0250
CURVE 65*	
T = 293.	
1.5	0.040
CURVE 66*	
T = 293.	
1.5	0.050
CURVE 67*	
T = 293.	
1.5	0.035
CURVE 68*	
T = 293.	
1.5	0.020
CURVE 69*	
T = 293.	
1.5	0.015
CURVE 70*	
T = 293.	
1.5	0.020
CURVE 71*	
T = 293.	
1.5	0.0675
CURVE 72*	
T = 293.	
1.5	0.354
CURVE 73*	
T = 293.	
1.5	0.442
CURVE 74*	
T = 293.	
1.5	0.171
CURVE 75*	
T = 293.	
0.5	0.025
CURVE 76*	
T = 293.	
0.5	0.015
CURVE 77*	
T = 293.	
0.5	0.0296
CURVE 78*	
T = 293.	
0.5	0.0410
CURVE 79*	
T = 293.	
0.5	0.0334
CURVE 80*	
T = 293.	
0.5	0.0303
CURVE 81*	
T = 293.	
0.5	0.0189
CURVE 82*	
T = 293.	
0.5	0.013
1.5	0.045
CURVE 83*	
T = 293.	
0.5	0.0271
CURVE 84*	
T = 293.	
0.5	0.043
1.5	0.31
CURVE 85*	
T = 293.	
0.5	0.245
CURVE 86*	
T = 293.	
0.5	0.484
CURVE 87*	
T = 293.	
0.5	0.342
CURVE 88*	
T = 293.	
1.5	0.232
CURVE 89*	
T = 293.	
1.5	0.547
CURVE 90*	
T = 293.	
1.5	0.589

* NOT SHOWN IN FIGURE.

TABLE 1-12. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 91*	
T = 293.	
1.5	0.246
CURVE 92*	
T = 293.	
1.5	0.075
CURVE 93*	
T = 293.	
1.5	0.0944
CURVE 94*	
T = 293.	
1.5	0.060
CURVE 95*	
T = 293.	
1.5	0.479
CURVE 96*	
T = 293.	
1.5	0.19
CURVE 97*	
T = 293.	
1.5	0.097
CURVE 98*	
T = 293.	
1.5	0.053

λ	ρ
CURVE 99*	
T = 293.	
1.5	0.0287
CURVE 100*	
T = 293.	
1.5	0.023
CURVE 101*	
T = 293.	
1.5	0.032
CURVE 102*	
T = 293.	
1.5	0.0167
CURVE 103*	
T = 293.	
1.5	0.217
CURVE 104*	
T = 293.	
1.5	0.345
CURVE 105*	
T = 293.	
1.5	0.118
CURVE 106*	
T = 293.	
1.5	0.0203

λ	ρ
CURVE 107*	
T = 293.	
1.5	0.179
CURVE 108*	
T = 293.	
1.5	0.036
CURVE 109*	
T = 293.	
1.5	0.020
CURVE 110*	
T = 293.	
1.5	0.030
CURVE 111*	
T = 293.	
0.5	0.0346
CURVE 112*	
T = 293.	
0.5	0.0089
CURVE 113	
T = 303.	
0.249	0.223
0.272	0.232
0.294	0.248
0.307	0.271
0.322	0.313
0.342	0.366
0.349	0.392
0.358	0.419
0.377	0.437

λ	ρ
CURVE 113 (CONT.)	
0.404	0.445
0.420	0.457
0.460	0.484
0.497	0.505
0.567	0.514
0.620	0.517
0.690	0.513
0.751	0.506
0.818	0.519
0.879	0.561
0.946	0.596
1.071	0.642
1.196	0.664
1.485	0.704
1.836	0.727
1.995	0.713
CURVE 114	
T = 303.	
0.249	0.260
0.274	0.298
0.303	0.364
0.322	0.414
0.346	0.454
0.376	0.487
0.416	0.513
0.467	0.528
0.527	0.539
0.619	0.539
0.688	0.532
0.787	0.520
0.853	0.543
0.939	0.586
1.035	0.650
1.091	0.670
1.273	0.705
1.402	0.710
1.492	0.732
1.570	0.742

λ	ρ
CURVE 114 (CONT.)	
1.698	0.742
1.745	0.752
1.803	0.755
1.888	0.755
1.995	0.737
CURVE 115	
T = 303.	
0.249	0.000
0.298	0.006
0.338	0.012
0.363	0.017
0.400	0.016
0.446	0.014
0.474	0.018
0.500	0.021
0.599	0.021
0.706	0.025
0.736	0.031
0.812	0.037
0.909	0.045
0.946	0.063
1.047	0.095
1.124	0.127
1.227	0.170
1.355	0.218
1.383	0.235
1.409	0.271
1.552	0.297
1.595	0.328
1.667	0.354
1.811	0.402
1.995	0.461
CURVE 116*	
T = 293.	
1.2	0.837
1.8	0.929

λ	ρ
CURVE 117*	
T = 293.	
1.2	0.820
1.8	0.910
CURVE 118*	
T = 293.	
1.2	0.690
1.8	0.741
CURVE 119*	
T = 293.	
1.2	0.662
1.8	0.731
CURVE 120*	
T = 293.	
1.2	0.719
1.8	0.824
CURVE 121*	
T = 293.	
1.2	0.693
1.8	0.771
CURVE 122*	
T = 293.	
1.2	0.859
CURVE 123*	
T = 293.	
1.2	0.870

* NOT SHOWN IN FIGURE.

TABLE 1-12. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
CURVE 124*		CURVE 132*		CURVE 140*		CURVE 148*		CURVE 156*		CURVE 164*	
T = 293.		T = 293.		T = 293.		T = 293.		T = 293.		T = 293.	
1.2	0.871	1.2	0.630	1.2	0.633	1.2	0.612	1.2	0.512	1.2	0.782
CURVE 125*		CURVE 133*		CURVE 141*		CURVE 149*		CURVE 157*		CURVE 165*	
T = 293.		T = 293.		T = 293.		T = 293.		T = 293.		T = 293.	
1.2	0.843	1.2	0.591	1.2	0.614	1.2	0.617	1.2	0.515	1.2	0.748
CURVE 126*		CURVE 134*		CURVE 142*		CURVE 150*		CURVE 158*		CURVE 166*	
T = 293.		T = 293.		T = 293.		T = 293.		T = 293.		T = 293.	
1.2	0.753	1.2	0.687	1.2	0.602	1.2	0.617	1.2	0.518	1.2	0.716
CURVE 127*		CURVE 135*		CURVE 143*		CURVE 151*		CURVE 159*		CURVE 167*	
T = 293.		T = 293.		T = 293.		T = 293.		T = 293.		T = 293.	
1.2	0.575	1.2	0.693	1.2	0.600	1.2	0.613	1.2	0.519	1.2	0.691
CURVE 128*		CURVE 136*		CURVE 144*		CURVE 152*		CURVE 160*		CURVE 168*	
T = 293.		T = 293.		T = 293.		T = 293.		T = 293.		T = 293.	
1.2	0.524	1.2	0.694	1.2	0.604	1.2	0.604	1.2	0.520	1.2	0.690
CURVE 129*		CURVE 137*		CURVE 145*		CURVE 153*		CURVE 161*		CURVE 169*	
T = 293.		T = 293.		T = 293.		T = 293.		T = 293.		T = 293.	
1.2	0.524	1.2	0.692	1.2	0.607	1.2	0.584	1.2	0.515	1.2	0.689
CURVE 130*		CURVE 138*		CURVE 146*		CURVE 154*		CURVE 162*		CURVE 170*	
T = 293.		T = 293.		T = 293.		T = 293.		T = 293.		T = 293.	
1.2	0.591	1.2	0.681	1.2	0.609	1.2	0.541	1.2	0.037	1.2	0.650
CURVE 131*		CURVE 139*		CURVE 147*		CURVE 155*		CURVE 163*		CURVE 171*	
T = 293.		T = 293.		T = 293.		T = 293.		T = 293.		T = 293.	
1.2	0.642	1.2	0.660	1.2	0.608	1.2	0.521	1.2	0.021	1.2	0.689

* NOT SHOWN IN FIGURE.

TABLE 1-12. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm ; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 172*	
T = 293.	
1.2	0.595
CURVE 173*	
T = 293.	
1.2	0.603
CURVE 174*	
T = 293.	
1.2	0.601
CURVE 175	
T = 293.	
2.03	0.571
2.07	0.450
2.13	0.457
2.14	0.527
2.21	0.461
2.24	0.533
2.28	0.432
2.34	0.465
2.35	0.438
2.40	0.455
2.54	0.476
2.58	0.496
2.62	0.469
2.67	0.489
2.77	0.439
2.83	0.379
2.90	0.346
2.92	0.323
2.97	0.332
3.01	0.307
3.05	0.320
3.13	0.320
3.31	0.354
3.31	0.366

λ	ρ
CURVE 175 (CONT.)	
3.81	0.521
3.94	0.532
4.03	0.549
4.17	0.554
4.29	0.580
4.43	0.592
4.49	0.600
4.61	0.607
4.66	0.608
4.66	0.565
4.80	0.534
4.82	0.558
4.99	0.629
5.18	0.654
5.31	0.667
5.52	0.675
5.68	0.689
5.95	0.700
6.12	0.700
6.25	0.707
6.31	0.718
6.61	0.739
6.81	0.739
7.08	0.755
7.23	0.755
7.38	0.766
7.51	0.766
8.28	0.815
8.44	0.815
8.75	0.824
8.97	0.824
9.20	0.833
9.43	0.833
10.20	0.852
10.47	0.848
10.72	0.856
11.22	0.858
11.55	0.865
12.07	0.870
12.53	0.875

λ	ρ
CURVE 175 (CONT.)	
12.84	0.878
13.09	0.888
13.39	0.888
13.74	0.892
14.09	0.892
14.72	0.905
CURVE 176	
T = 293.	
2.07	0.477
2.09	0.410
2.15	0.511
2.20	0.438
2.24	0.470
2.28	0.465
2.31	0.441
2.38	0.495
2.40	0.444
2.44	0.460
2.51	0.468
2.55	0.493
2.60	0.468
2.67	0.488
2.74	0.473
2.74	0.405
2.79	0.366
2.83	0.356
2.86	0.317
3.00	0.294
3.11	0.294
3.21	0.311
3.37	0.347
3.37	0.379
3.48	0.395
3.66	0.455
3.76	0.486
3.84	0.501
4.03	0.522
4.27	0.543

λ	ρ
CURVE 176 (CONT.)	
4.48	0.575
4.61	0.582
4.61	0.571
4.65	0.564
4.70	0.501
4.74	0.469
4.89	0.589
5.04	0.606
5.41	0.642
5.61	0.657
5.81	0.662
6.03	0.656
6.20	0.668
6.46	0.697
6.58	0.706
6.72	0.707
6.84	0.697
7.00	0.702
7.11	0.710
7.39	0.720
7.62	0.739
7.89	0.765
8.22	0.774
8.51	0.780
9.07	0.803
9.48	0.817
9.80	0.822
9.96	0.820
10.05	0.825
11.17	0.836
11.72	0.847
12.14	0.867
12.48	0.877
13.00	0.879
13.53	0.876
13.81	0.882
14.05	0.896
14.39	0.912
14.67	0.915

λ	ρ
CURVE 177	
T = 293.	
2.00	0.787
2.04	0.738
2.09	0.833
2.16	0.614
2.18	0.763
2.18	0.663
2.22	0.691
2.26	0.648
2.32	0.638
2.37	0.689
2.39	0.635
2.41	0.619
2.44	0.634
2.47	0.610
2.51	0.625
2.54	0.615
2.57	0.633
2.61	0.616
2.64	0.630
2.72	0.593
2.74	0.551
2.81	0.455
2.93	0.382
2.98	0.386
3.09	0.375
3.23	0.398
3.31	0.418
3.61	0.552
3.74	0.585
3.81	0.609
4.05	0.636
4.22	0.662
4.39	0.669
4.49	0.685
4.57	0.690
4.64	0.683
4.70	0.642
4.78	0.570
4.87	0.652

λ	ρ
CURVE 177 (CONT.)	
4.90	0.689
5.02	0.715
5.12	0.724
5.53	0.748
5.76	0.756
5.88	0.756
6.09	0.742
6.30	0.756
6.45	0.776
6.64	0.785
6.81	0.776
7.00	0.768
7.16	0.775
7.27	0.782
7.48	0.784
7.85	0.818
8.25	0.831
8.80	0.846
9.32	0.846
9.62	0.840
9.93	0.858
10.36	0.850
10.60	0.842
10.83	0.842
11.13	0.858
11.92	0.857
12.59	0.866
13.16	0.880
13.51	0.888
13.87	0.879
14.67	0.901
CURVE 178	
T = 293.	
2.07	0.383
2.14	0.381
2.14	0.348
2.23	0.378
2.27	0.363

* NOT SHOWN IN FIGURE.

TABLE 1-12. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
CURVE 178(CONT.)		CURVE 178(CONT.)		CURVE 179(CONT.)		CURVE 179(CONT.)		CURVE 180(CONT.)*		CURVE 182*	
2.28	0.386	6.60	0.629	2.54	0.428	8.32	0.717	3.00	0.940	T = 293.	
2.33	0.374	6.69	0.636	2.58	0.443	8.98	0.736	3.08	0.958	2.8	0.49
2.38	0.390	6.87	0.636	2.63	0.418	9.23	0.738	3.26	0.947	3.8	0.60
2.40	0.370	7.08	0.631	2.71	0.446	9.34	0.746	3.33	0.964	5.0	0.71
2.44	0.405	7.32	0.636	2.83	0.438	9.63	0.747	3.55	0.952	10.6	0.84
2.47	0.392	7.49	0.646	2.89	0.422	9.75	0.750	3.83	0.978		
2.52	0.408	7.86	0.661	2.92	0.433	10.02	0.750	3.97	0.962	CURVE 183*	
2.58	0.389	8.15	0.679	2.98	0.433	10.13	0.754	4.03	0.975	T = 293.	
2.65	0.412	8.54	0.703	3.01	0.440	10.39	0.754	4.19	0.968	2.8	0.96
2.72	0.412	8.84	0.703	3.07	0.440	10.81	0.760	4.28	0.979	3.8	0.96
2.77	0.351	9.35	0.730	3.25	0.461	11.34	0.771	4.37	0.979	5.0	0.96
2.83	0.323	9.50	0.730	3.49	0.500	11.98	0.771	4.49	0.968	10.6	0.95
2.87	0.275	9.63	0.728	3.62	0.513	12.45	0.779	4.59	0.968		
2.92	0.266	9.71	0.734	3.76	0.527	12.88	0.789	4.71	0.976	CURVE 184*	
2.98	0.266	9.84	0.742	3.85	0.527	13.14	0.791	4.87	0.970	T = 293.	
3.04	0.240	10.10	0.746	3.88	0.538	13.76	0.804	5.05	0.980	2.8	0.94
3.21	0.250	10.52	0.746	3.98	0.541	14.17	0.808	6.00	0.980	3.8	0.95
3.21	0.262	11.00	0.762	4.16	0.558	14.53	0.808	6.99	0.984	5.0	0.96
3.42	0.302	11.29	0.765	4.26	0.580	14.63	0.805	7.63	0.991	10.6	0.96
3.50	0.324	11.58	0.764	4.36	0.576			7.98	0.984		
3.66	0.375	11.78	0.771	4.67	0.588	CURVE 180*		8.24	0.994	CURVE 185	
3.82	0.416	12.43	0.778	5.13	0.619	T = 293.		8.41	0.987	T = 293.	
3.99	0.438	12.74	0.796	5.73	0.630			8.88	0.991	2.00	0.706
4.23	0.455	13.35	0.795	5.96	0.641	2.00	0.928	9.02	0.988	2.02	0.641
4.33	0.481	13.84	0.788	6.05	0.650	2.06	0.818	9.62	0.988	2.09	0.723
4.42	0.478	14.05	0.781	6.38	0.653	2.10	0.963	9.81	0.993	2.11	0.628
4.53	0.496	14.16	0.777	6.50	0.665	2.17	0.874	10.00	0.989	2.14	0.709
4.64	0.501	14.58	0.780	6.63	0.672	2.23	0.966	12.00	0.988	2.16	0.638
4.70	0.493			6.80	0.671	2.28	0.882	12.22	0.992	2.20	0.599
4.82	0.407	CURVE 179		6.95	0.680	2.30	0.957	14.67	0.992	2.24	0.666
4.88	0.463	T = 293.		7.09	0.680	2.34	0.896			2.27	0.619
4.93	0.479			2.8	0.44	2.36	0.915	CURVE 181*		2.32	0.666
4.98	0.516	2.07	0.459	3.8	0.53	2.43	0.931	T = 293.		2.37	0.632
5.11	0.534	2.15	0.411	5.0	0.62	2.47	0.968			2.41	0.671
5.42	0.554	2.19	0.387	10.6	0.76	2.51	0.952	2.8	0.34	2.49	0.641
5.57	0.571	2.28	0.427	7.33	0.689	2.58	0.975	3.8	0.45	2.53	0.660
5.94	0.584	2.36	0.396	7.39	0.695	2.66	0.928	5.0	0.57	2.57	0.640
6.08	0.584	2.40	0.413	7.56	0.696	2.70	0.945	10.6	0.78		
6.19	0.595	2.45	0.406	7.70	0.704	2.78	0.961				
6.39	0.597	2.49	0.424	8.12	0.707	2.83	0.948				

*NOT SHOWN IN FIGURE.

TABLE 1-12. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm ; TEMPERATURE, T, K; REFLECTANCE, ρ]

CURVE 185 (CONT.)

λ	ρ
2.61	0.666
2.75	0.299
2.85	0.191
2.90	0.211
2.97	0.196
3.03	0.247
3.08	0.240
3.20	0.288
3.24	0.315
3.24	0.330
3.31	0.340
3.31	0.357
3.39	0.365
3.58	0.509
3.64	0.517
3.67	0.552
3.79	0.563
3.87	0.554
3.97	0.554
4.07	0.541
4.07	0.549
4.18	0.554
4.28	0.561
4.28	0.566
4.35	0.585
4.46	0.592
4.52	0.603
4.71	0.613
4.76	0.612
4.81	0.616
4.93	0.616
5.08	0.620
5.25	0.607
5.53	0.599
5.59	0.591
5.71	0.582
5.78	0.567
5.86	0.540
6.03	0.511
6.22	0.535

CURVE 185 (CONT.)

λ	ρ
6.25	0.548
6.35	0.577
6.50	0.602
6.61	0.607
6.73	0.594
6.83	0.590
7.03	0.566
7.15	0.519
7.44	0.332
7.91	0.152
8.34	0.063
8.58	0.056
8.71	0.044
8.83	0.044
9.07	0.062
9.34	0.098
9.45	0.115
9.69	0.136
9.82	0.146
10.02	0.135
10.44	0.057
10.68	0.037
10.87	0.026
11.00	0.026
11.12	0.039
11.28	0.049
11.74	0.049
12.06	0.069
12.53	0.069
13.07	0.081
13.35	0.077
13.50	0.077
13.69	0.086
13.86	0.091
14.24	0.091
14.63	0.102

CURVE 186
T = 293.

λ	ρ
2.8	0.14
3.8	0.43
5.0	0.48
10.6	0.02

CURVE 187*
T = 293.

λ	ρ
2.8	0.22
3.8	0.51
5.0	0.58
10.6	0.03

CURVE 188
T = 293.

λ	ρ
2.8	0.14
3.8	0.43
5.0	0.48
10.6	0.02

CURVE 189
T = 293.

λ	ρ
2.8	0.28
3.8	0.43
5.0	0.49
10.6	0.02

CURVE 190*
T = 293.

λ	ρ
0.351	0.705
0.454	0.738
0.565	0.751
0.680	0.746
0.772	0.735
0.844	0.771
0.913	0.809

CURVE 190 (CONT.)*

λ	ρ
0.974	0.843
1.043	0.869
1.097	0.883
1.183	0.896
1.279	0.907
1.429	0.919
1.547	0.919
1.979	0.924

CURVE 191*
T = 293.

λ	ρ
0.352	0.588
0.455	0.616
0.517	0.635
0.572	0.656
0.632	0.635
0.690	0.615
0.734	0.603
0.760	0.603
0.801	0.620
0.858	0.627
0.894	0.642
0.939	0.666
0.984	0.681
1.038	0.700
1.099	0.715

*NOT SHOWN IN FIGURE.

g. Angular Spectral Reflectance (Incident Angle Dependence)

Room temperature values of the angular spectral reflectance for wavelengths 1.2 μm and 1.8 μm as a function of incidence angle are listed in Table 1-14 and shown in Figure 1-22.

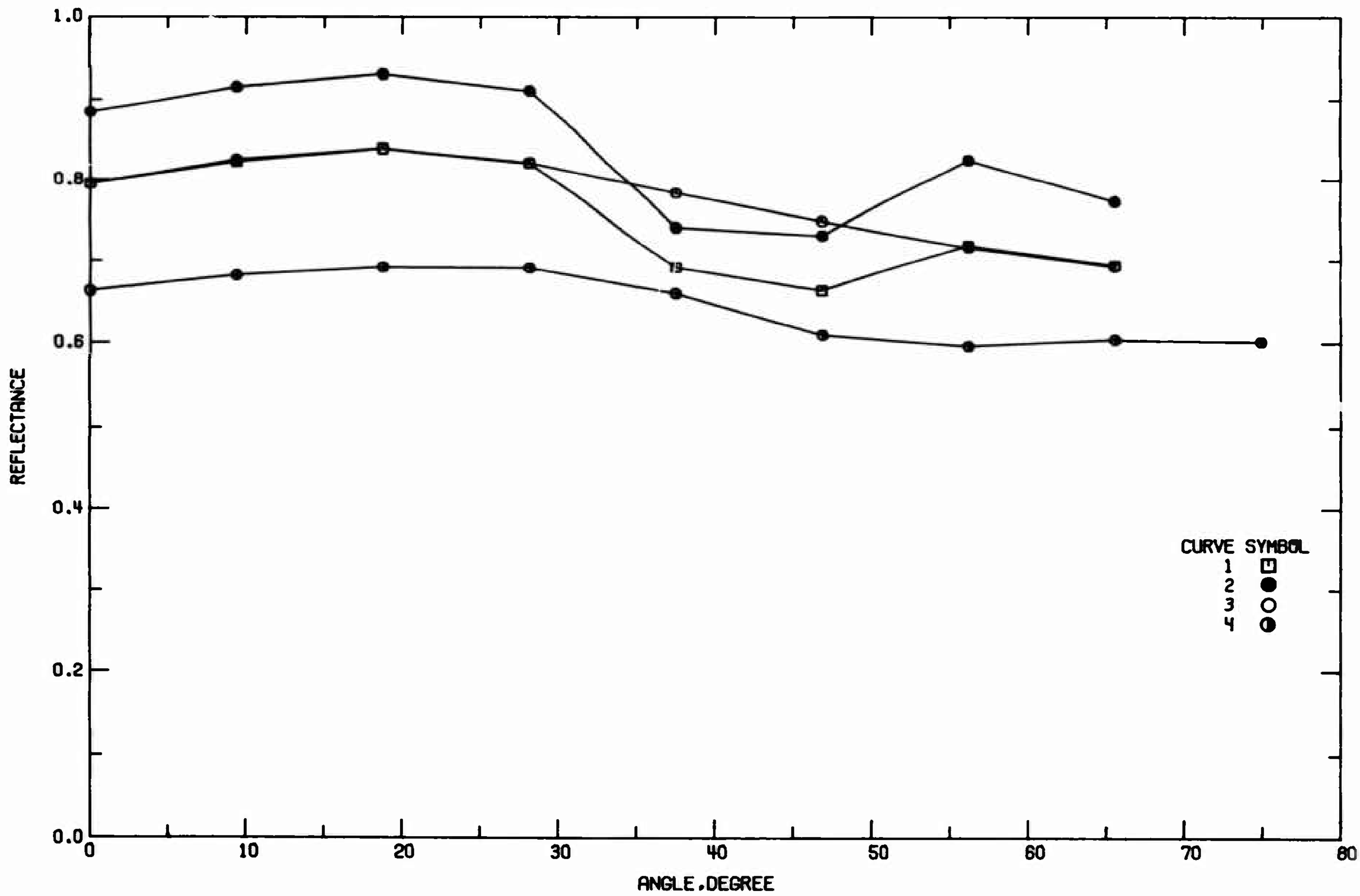


FIGURE 1-22. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (INCIDENT ANGLE DEPENDENCE).

TABLE 1-13. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (Incident Angle Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T29563	Eberhart, R.C.	1960	1.2	293	Aluminum 24ST, Polished	Specimen 2.22 cm discs, 0.16 to 0.32 cm thick; sample surface prepared by standard metallographic techniques, average horizontal peak to peak distance is 30 μm, groove depth (average displacement from mean surface line) is 0.40 μm, integrating sphere used with PbS detector; reference standard MgO; data extracted from figure; measurement temperature not given explicitly, 293 K assigned; $\theta = 20°$, $\omega' = 2\pi$.
2	T29563	Eberhart, R.C.	1960	1.8	293	Aluminum 24ST, Polished	Similar to the above specimen
3	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Polished; Beckman DK2 spectrometer integrating sphere used for measurement; MgO reference standard; data extracted from figure; measurement temperature not given explicitly, 293 K assigned; $\theta = 0°$ to $70°$, $\omega' = 2\pi$.
4	T19294	Rolling, R.E. and Seban, R.A.	1960	1.2	293	Aluminum 24ST	Roughened sample; surface roughened with sandpaper, scratches parallel; course structure - peak to peak depth 6.35 μm, spacing, 34 μm, fine structure - peak to peak depth, 1 μm; Beckman DK2 spectrometer integrating sphere used for measurement; MgO reference standard; data extracted from figure; measurement temperature not given explicitly, 293 K assigned; $\theta = 0°$ to $80°$, $\omega' = 2\pi$.

TABLE 1-14. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 2024 (INCIDENT ANGLE DEPENDENCE)

[ANGLE, θ, DEGREE; TEMPERATURE, T, K; REFLECTANCE, ρ]

θ	ρ	θ	ρ
CURVE 1		CURVE 4(CONT.)	
T = 293.			
		30.	0.689
0.	0.794	40.	0.658
10.	0.822	50.	0.609
20.	0.837	60.	0.595
30.	0.820	70.	0.603
40.	0.690	80.	0.601
50.	0.662		
60.	0.719		
70.	0.693		
CURVE 2			
T = 293.			
0.	0.882		
10.	0.914		
20.	0.929		
30.	0.910		
40.	0.741		
50.	0.731		
60.	0.824		
70.	0.771		
CURVE 3			
T = 293.			
0.	0.794		
10.	0.824		
20.	0.837		
30.	0.821		
40.	0.782		
50.	0.748		
60.	0.716		
70.	0.691		
CURVE 4			
T = 293.			
0.	0.661		
10.	0.680		
20.	0.690		

h. Normal Spectral Absorptance (Wavelength Dependence)

There are two sets of experimental data available for the wavelength dependence (2.53-20.0 μm) of the normal spectral absorptance of Aluminum Alloy 2024 for polished surface conditions. These are listed in Table 1-17 and shown in Figure 1-24.

(1) Highly Polished Aluminum Alloy 2024

The recommended values at 293 K listed in Table 1-15 and shown in Figure 1-23 for highly polished Aluminum Alloy 2024 were generated from the measurements of Schriempf and Wieting [A00003] and are believed accurate to $\pm$ 10% over the entire wavelength range.

(2) Highly Polished Alclad Aluminum Alloy 2024

The recommended values at 293 K are listed in Table 1-15 and shown in Figure 1-25 for highly polished alclad Aluminum Alloy 2024. These values were generated with the relationship discussed in Section 4.20, based on Eq. (2.5-5), and are believed accurate to $\pm$ 10% over the entire wavelength range. The provisional values for highly polished alclad Aluminum Alloy 2024 were calculated for temperatures of 450, 600, and 750 K by the relationship discussed in Section 4.20, based on Eq. (2.5-5), are listed in Table 1-15 and shown in Figure 1-25 and are believed accurate to $\pm$ 20% over the entire wavelength range.

(3) Oxidized Aluminum Alloy 2024

The provisional values are listed in Table 1-15 and shown in Figure 1-26 for oxidized Aluminum Alloy 2024 at 823 K. These values are consistent with the normal spectral emittance values of Blau, et al. [T16606] and are believed accurate to $\pm$20% over the entire wavelength range.

TABLE 1-15. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α	λ	α	λ	α	λ	α
HIGHLY POLISHED T = 293		HIGHLY POLISHED ALCLAD T = 293		HIGHLY POLISHED ALCLAD T = 450		HIGHLY POLISHED ALCLAD T = 600		HIGHLY POLISHED ALCLAD T = 750		OXIDIZED ALLOY T = 823	
2.20	0.0980	2.5	0.067	2.5	0.071A†	2.5	0.073A†	2.5	0.075A†	2.0	0.426A†
2.80	0.0760	2.8	0.057	2.8	0.063A	2.8	0.067A	2.8	0.069A	2.2	0.418A
3.00	0.0697	3.0	0.052	3.0	0.059A	3.0	0.063A	3.0	0.066A	2.5	0.410A
3.50	0.0575	3.5	0.044	3.5	0.052A	3.5	0.056A	3.5	0.060A	2.8	0.403A
3.80	0.0524	3.8	0.041	3.8	0.049A	3.8	0.053A	3.8	0.057A	3.0	0.399A
4.00	0.0498	4.0	0.039	4.0	0.046A	4.0	0.051A	4.0	0.055A	3.2	0.394A
4.50	0.0440	4.5	0.035	4.5	0.043A	4.5	0.047A	4.5	0.051A	3.5	0.386A
5.00	0.0402	5.0	0.033	5.0	0.040A	5.0	0.044A	5.0	0.048A	3.8	0.381A
5.50	0.0375	5.5	0.031	5.5	0.037A	5.5	0.042A	5.5	0.046A	4.0	0.376A
6.00	0.0355	6.0	0.029	6.0	0.035A	6.0	0.040A	6.0	0.043A	4.2	0.374A
6.50	0.0338	6.5	0.027	6.5	0.034A	6.5	0.038A	6.5	0.042A	4.5	0.366A
7.00	0.0323	7.0	0.026	7.0	0.032A	7.0	0.037A	7.0	0.040A	4.8	0.362A
7.50	0.0310	7.5	0.025	7.5	0.031A	7.5	0.035A	7.5	0.039A	5.0	0.360A
8.00	0.0298	8.0	0.024	8.0	0.030A	8.0	0.034A	8.0	0.037A	5.2	0.356A
8.50	0.0287	8.5	0.023	8.5	0.029A	8.5	0.033A	8.5	0.036A	5.5	0.351A
9.00	0.0278	9.0	0.023	9.0	0.028A	9.0	0.032A	9.0	0.035A	5.8	0.346A
9.50	0.0272	9.5	0.022	9.5	0.027A	9.5	0.031A	9.5	0.034A	6.0	0.342A
10.00	0.0270	10.0	0.021	10.0	0.026A	10.0	0.030A	10.0	0.033A	6.2	0.340A
10.60	0.0262	10.5	0.021	10.5	0.026A	10.5	0.029A	10.5	0.032A	6.5	0.336A
11.00	0.0258	11.0	0.020	11.0	0.025A	11.0	0.029A	11.0	0.032A	7.0	0.330A
11.50	0.0254	11.5	0.020	11.5	0.025A	11.5	0.028A	11.5	0.031A	7.2	0.328A
12.00	0.0250	12.0	0.019	12.0	0.024A	12.0	0.028A	12.0	0.030A	7.5	0.323A
12.50	0.0246	12.5	0.019	12.5	0.024A	12.5	0.027A	12.5	0.030A	8.0	0.317A
13.00	0.0242	13.0	0.019	13.0	0.023A	13.0	0.026A	13.0	0.029A	8.5	0.310A
13.50	0.0239	13.5	0.018	13.5	0.023A	14.0	0.025A	13.5	0.029A	9.0	0.303A
14.00	0.0235	14.0	0.018	14.0	0.022A	14.5	0.025A	14.0	0.028A	9.5	0.296A
14.50	0.0232	14.5	0.017	14.5	0.022A	15.0	0.025A	14.5	0.028A	10.0	0.290A
15.00	0.0228	15.0	0.017	15.0	0.021A			15.0	0.027A	10.5	0.284A
										11.0	0.277A
										11.5	0.271A
										12.0	0.266A
										12.5	0.261A
										13.0	0.256A
										13.5	0.252A
										14.0	0.248A

† VALUE FOLLOWED BY AN "A" IS PROVISIONAL.

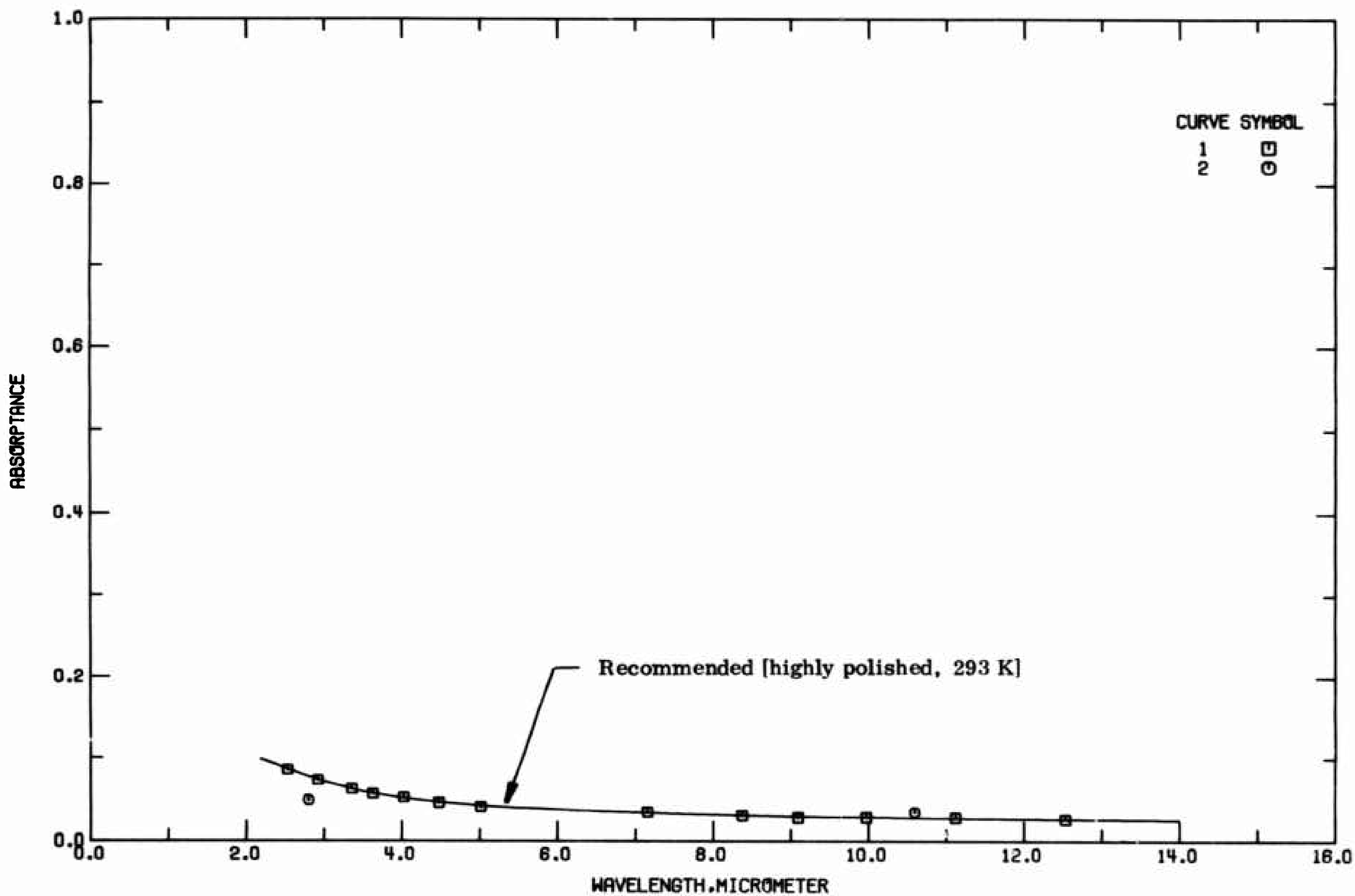


FIGURE 1-23. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

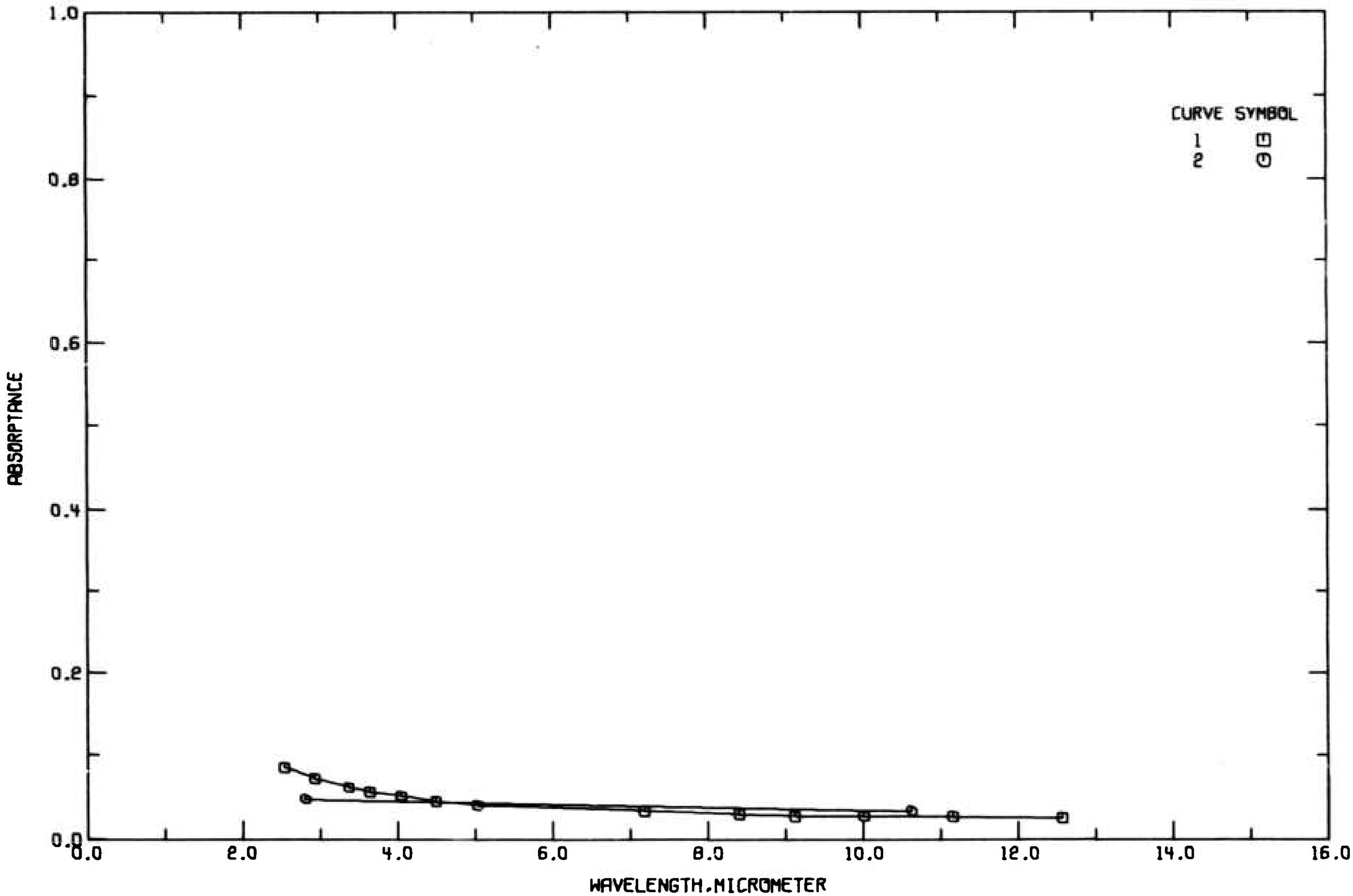


FIGURE 1-24. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

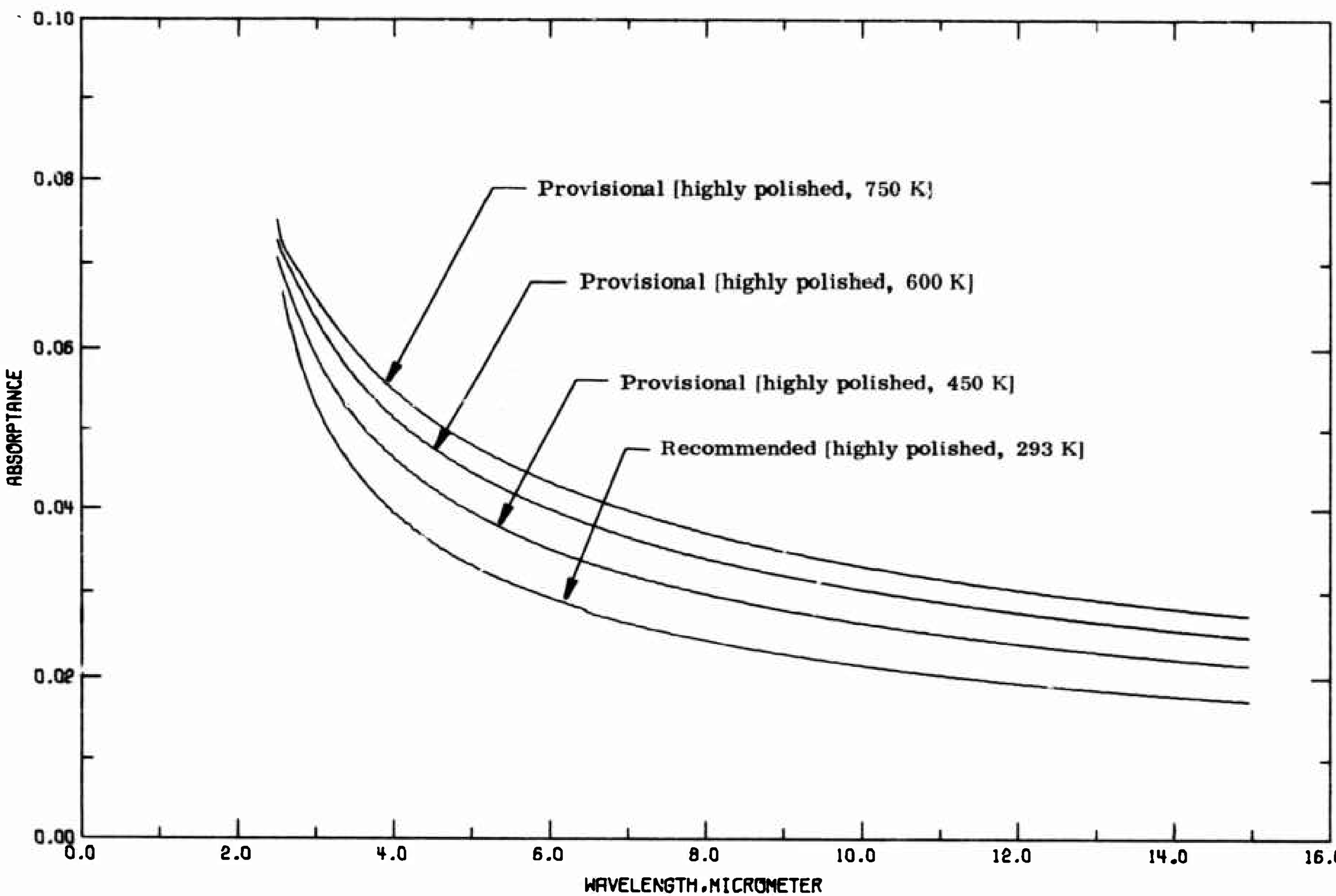


FIGURE 1-25. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF ALCLAD ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

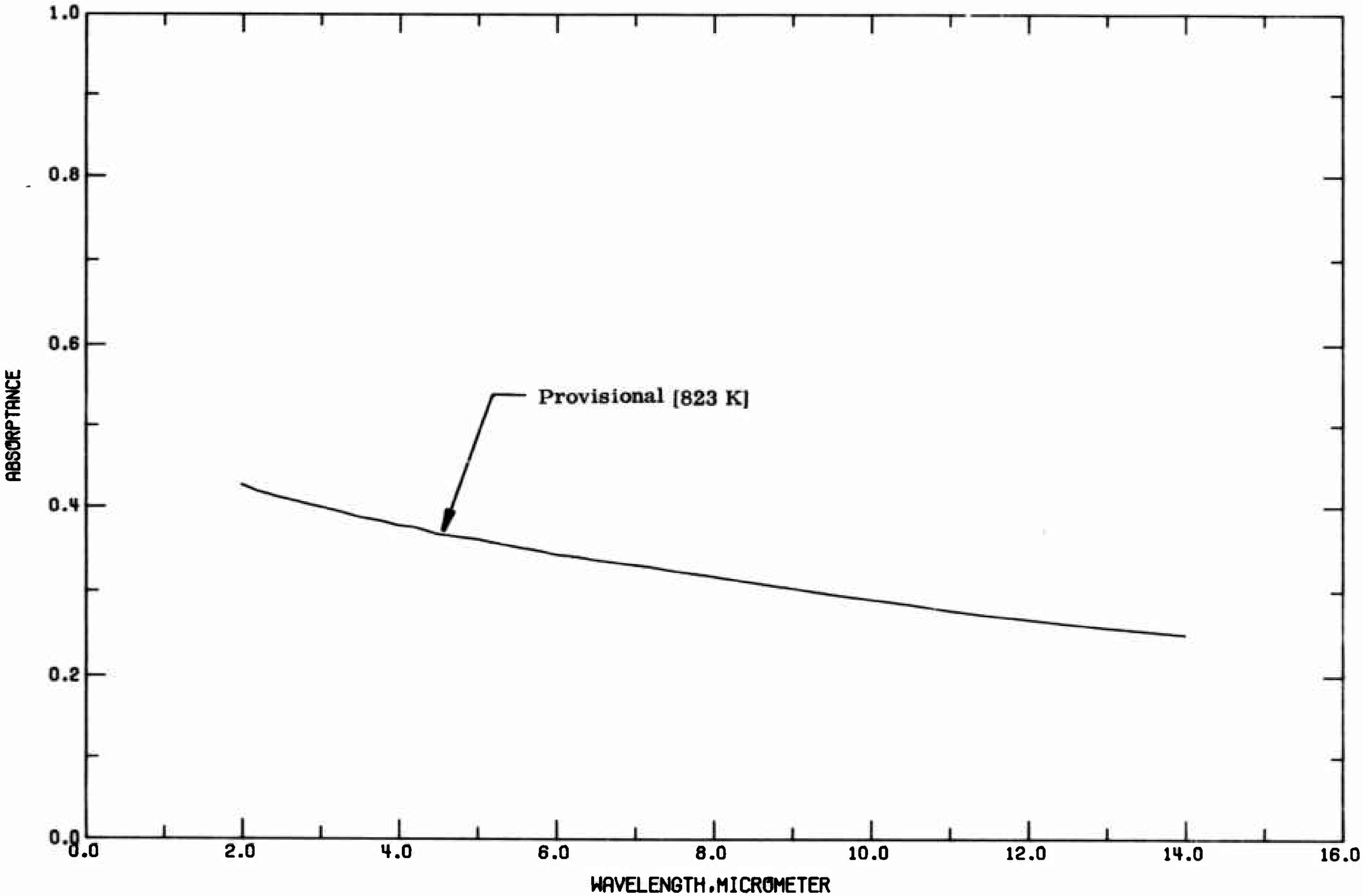


FIGURE 1-26. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF OXIDIZED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

TABLE 1-16. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 2024 (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00001	Schriemph, J.T. and Wieting, T.J.	1974	2.53–20.0	293	Aluminum Alloy	Author states specimen was "aluminum alloy very similar to 2024 aluminum"; author describes surface as "high quality"; reflectance was measured using a grating spectrometer, absorptance then calculated from $\alpha = 1 - \rho$; a gold reference mirror was used as a standard; data extracted from figure; measurement temperature specified as room temperature, 293 K assigned; $\theta \sim 0°$, reported error ± 0.1%.
2	A00016	Neighbours, J.R., (Editor)	1974	2.8, 10.6	293		Polished; measurement temperature specified as room temperature, 293 K assigned; $\theta = 0°$.

TABLE 1-17. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α
CURVE 1	
T = 293.	
2.53	0.0850
2.92	0.0717
3.36	0.0609
3.63	0.0551
4.03	0.0505
4.48	0.0439
5.02	0.0391
7.16	0.0329
8.38	0.0290
9.10	0.0266
9.98	0.0269
11.13	0.0265
12.54	0.0246
14.31	0.0229
16.66	0.0190
19.11	0.0195
20.00	0.0167
CURVE 2	
T = 293.	
2.8	0.047
10.6	0.033

i. Normal Spectral Absorptance (Temperature Dependence)

There are two sets of experimental data available for the temperature dependence (325-593 K) of the normal spectral absorptance of Aluminum Alloy 2024. These are listed in Table 1-20 and shown in Figure 1-28. This available data was not sufficient to generate recommended values, but values were calculated by the relation discussed in subsection 4.20, based on equation (2.5-5), for highly polished alclad Aluminum Alloy 2024 for wavelengths of 2.8, 3.8, 5.0, and 10.6 μm. These values are believed accurate to $\pm 20\%$ over the entire wavelength range and are listed in Table 1-18 and shown in Figure 1-27.

TABLE 1-18. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 2024 (TEMPERATURE DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α)

T	α	T	α	T	α	T	α
HIGHLY POLISHED ALCLAD λ = 2.8		HIGHLY POLISHED ALCLAD λ = 3.8		HIGHLY POLISHED ALCLAD λ = 5.0		HIGHLY POLISHED ALCLAD λ = 10.6	
250.0	0.054	250.0	0.038	250.0	0.030	250.0	0.019
293.0	0.057	293.0	0.041	293.0	0.033	293.0	0.021
300.0	0.057	300.0	0.041	300.0	0.033	300.0	0.021
350.0	0.060	350.0	0.044	350.0	0.036	350.0	0.023
400.0	0.062	400.0	0.046	400.0	0.038	400.0	0.024
450.0	0.063	450.0	0.04[illegible]	450.0	0.040	450.0	0.026
500.0	0.065	500.0	0.050	500.0	0.041	500.0	0.027
550.0	0.066	550.0	0.052	550.0	0.043	550.0	0.028
600.0	0.067	600.0	0.053	600.0	0.044	600.0	0.029
650.0	0.068	650.0	0.055	650.0	0.046	650.0	0.030
700.0	0.068	700.0	0.056	700.0	0.047	700.0	0.031
750.0	0.069	750.0	0.057	750.0	0.048	750.0	0.032

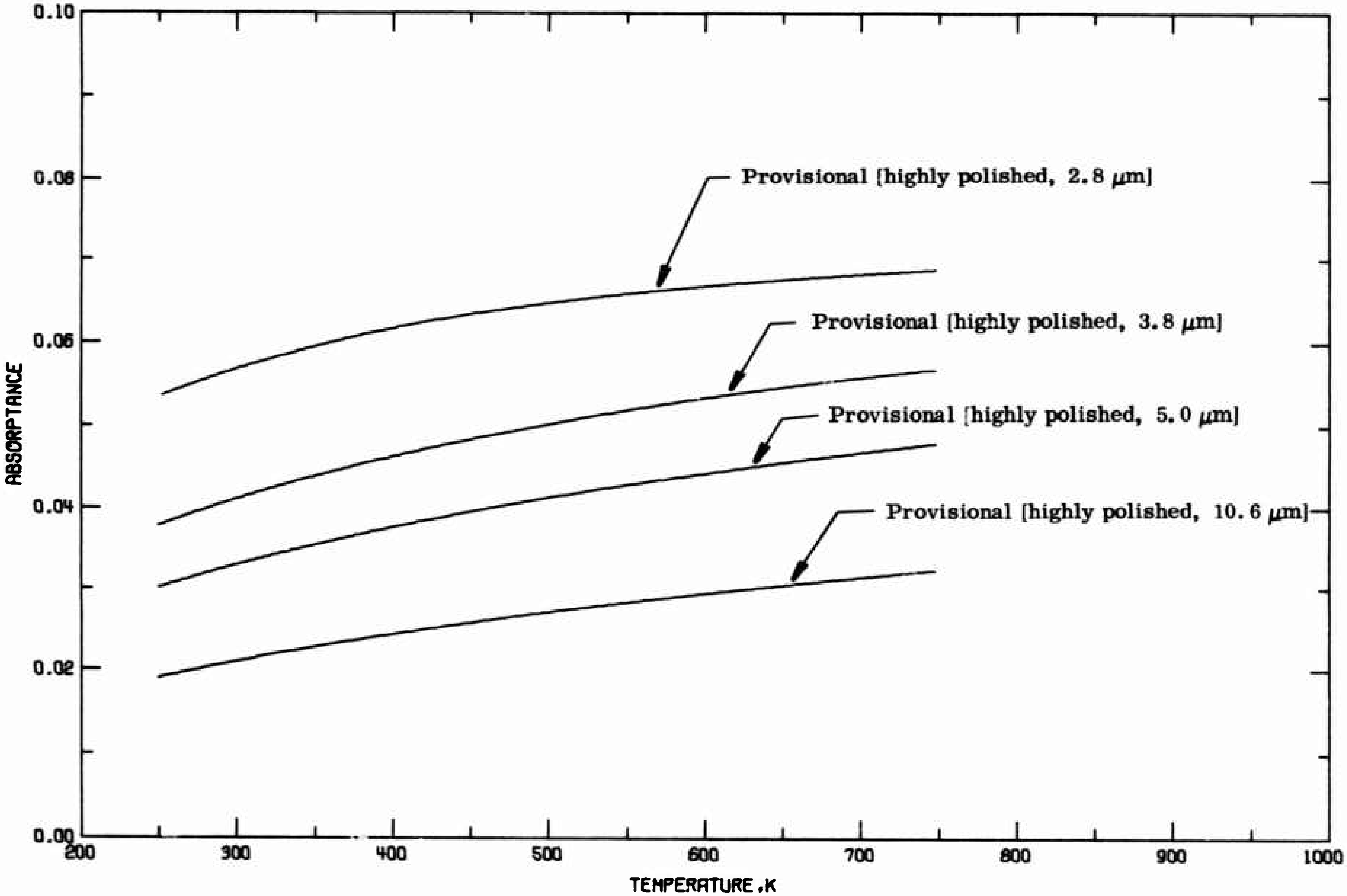


FIGURE 1-27. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF ALCLAD ALUMINUM ALLOY 2024 (TEMPERATURE DEPENDENCE).

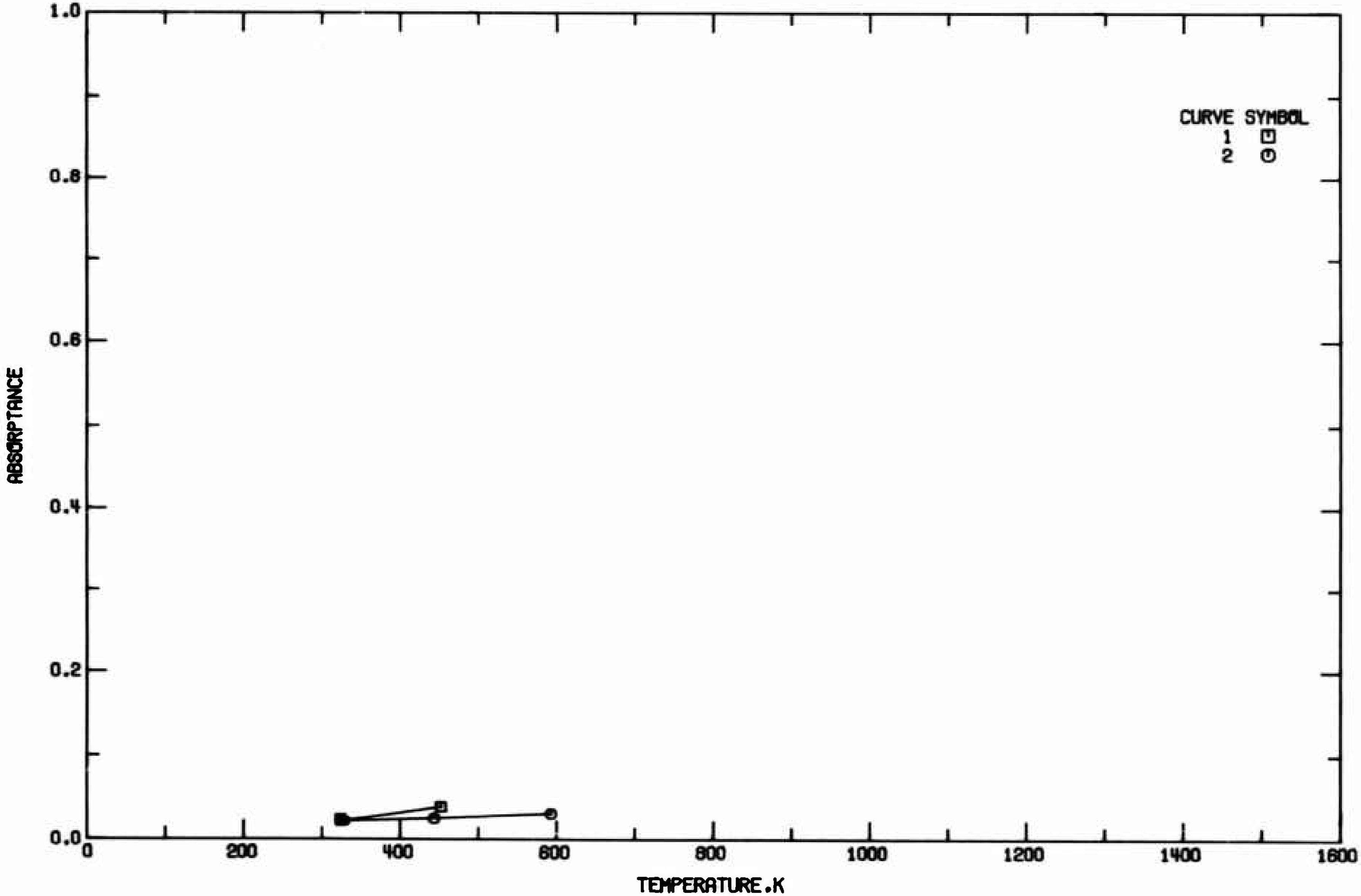


FIGURE 1-28. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 2024 (TEMPERATURE DEPENDENCE).

TABLE 1-19. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 2024 (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	E66194	Cunningham, S.S. and Laughlin, W.T.	1971-1973	10.6	325-453	2024 Alclad Aluminum	Specimen was circular; samples in as-received condition, then washed with methanol; room atm environment; sample irradiated with a 100 watt CO_2 Laser with intensity from 60-165 watts/cm^2; samples were uniformly heated by entire laser beam, thermocouples were attached to back of sample, one at center and one along perimeter; NSA calculated from temperature rise; author calls absorptance "coupling coefficient"; $\theta \sim 0°$, reported error ±0.3%.
2	E66194	Cunningham, S.S. and Laughlin, W.T.	1971-1973	10.6	328-593	2024 Alclad Aluminum	Specimen was 12.7 x 12.7 cm flat plate; sample in as-received condition, then washed with methanol; room atm environment; sample irradiated with a 5000 watt CO_2 Laser with intensity from 75-3700 watts/cm^2; beam size varied depending on intensity, but beam was always in center of plate; three thermocouples were attached to sample back, one at center of plate, another along line between opposing corners of plate, and another along line between two other opposing corners; NSA calculated from temperature rise; author calls absorptance "coupling coefficient"; $\theta \sim 0°$, reported error ±0.4%.

TABLE 1-20. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 2024 (TEMPERATURE DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α)

T	α
CURVE 1 λ = 10.6	
324.	0.024
325.	0.022
453.	0.039
CURVE 2 λ = 10.6	
328.	0.022
443.	0.025
593.	0.031

j. Angular Spectral Absorptance (Wavelength Dependence)

There are no experimental data available for this subproperty but provisional values are listed in Table 1-21 and shown in Figures 1-29, 1-30, and 1-31 for anodized, alodined ($\theta = 15°$), and alodined ($\theta = 45°$) Aluminum Alloy 2024, respectively. These were calculated from the provisional angular spectral reflectance data listed in Table 1-10 and shown in Figures 1-16, 1-18, and 1-20. The values are believed accurate to $\pm 15\%$ over the entire range for the anodized and alodined ($\theta = 15°$) Aluminum Alloy 2024 materials at 293 K. The alodined ($\theta = 45°$) Aluminum Alloy 2024 provisional values are accurate to $\pm 20\%$. These values apply only to the surface conditions cited in references, see Section 4.1-c.

TABLE 1-21. PROVISIONAL ANGULAR SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α
SULFURIC ACID ANODIZED, θ=15° T = 293	
0.30	0.740
0.35	0.640
0.40	0.550
0.50	0.482
0.60	0.474
0.70	0.475
0.80	0.481
0.83	0.482
0.90	0.434
1.00	0.380
1.20	0.320
1.40	0.292
1.60	0.274
1.80	0.268
2.00	0.279
2.20	0.301
2.40	0.341
2.60	0.422
2.80	0.779
2.85	0.807
2.90	0.810
2.95	0.808
3.00	0.797
3.20	0.677
3.40	0.592
3.60	0.526
3.80	0.484
4.00	0.454
4.20	0.428
4.40	0.410
4.60	0.396
4.80	0.389
5.00	0.384
5.20	0.382
5.40	0.390
5.60	0.406
5.80	0.442
5.90	0.476
6.00	0.484

λ	α
SULFURIC ACID ANODIZED, θ=15° T = 293 (CONT.)	
6.10	0.484
6.20	0.473
6.40	0.410
6.60	0.393
6.80	0.405
7.00	0.426
7.20	0.514
7.40	0.640
7.60	0.740
7.80	0.820
8.00	0.875
8.20	0.918
8.40	0.942
8.60	0.949
8.80	0.947
9.00	0.940
9.20	0.920
9.40	0.893
9.60	0.864
9.80	0.855
10.00	0.869
10.20	0.900
10.40	0.935
10.60	0.960
10.80	0.972
11.00	0.975
11.20	0.963
11.40	0.955
11.60	0.949
11.80	0.943
12.0	0.938
12.50	0.928
13.00	0.920
13.50	0.915
14.00	0.909
14.50	0.905
15.00	0.902

λ	α
CHROMATE ALODINED, θ=15° T = 293	
2.34	0.517
2.50	0.531
2.80	0.604
3.00	0.677
3.05	0.685
3.10	0.689
3.15	0.688
3.20	0.682
3.25	0.673
3.30	0.655
3.50	0.589
3.70	0.528
3.80	0.508
4.00	0.480
4.20	0.458
4.50	0.431
4.56	0.426
4.61	0.427
4.70	0.461
4.74	0.478
4.77	0.481
4.81	0.472
4.87	0.440
4.93	0.405
4.95	0.397
5.00	0.394
5.50	0.362
6.00	0.334
6.50	0.308
7.00	0.285
7.50	0.263
8.00	0.244
8.50	0.227
9.00	0.210
9.50	0.195
10.00	0.182
10.60	0.167
11.00	0.158
11.50	0.150

λ	α
CHROMATE ALODINED, θ=15° T = 293 (CONT.)	
12.00	0.142
12.50	0.135
13.00	0.129
13.50	0.123
14.00	0.118
14.50	0.113
15.00	0.109

λ	α
CHROMATE ALODINED, θ=45° T = 293	
2.00	0.240
2.20	0.258
2.40	0.288
2.60	0.358
2.80	0.552
3.00	0.620
3.10	0.618
3.20	0.606
3.40	0.550
3.60	0.470
3.80	0.408
4.00	0.366
4.20	0.338
4.40	0.320
4.50	0.316
4.60	0.320
4.70	0.400
4.72	0.412
4.76	0.414
4.80	0.412
4.90	0.320
5.00	0.298
5.20	0.280
5.40	0.270
5.60	0.260
5.80	0.252
6.00	0.246
7.00	0.220
8.00	0.200
9.00	0.181
10.00	0.164
10.60	0.156
11.00	0.150
12.00	0.136
13.80	0.127
14.00	0.116

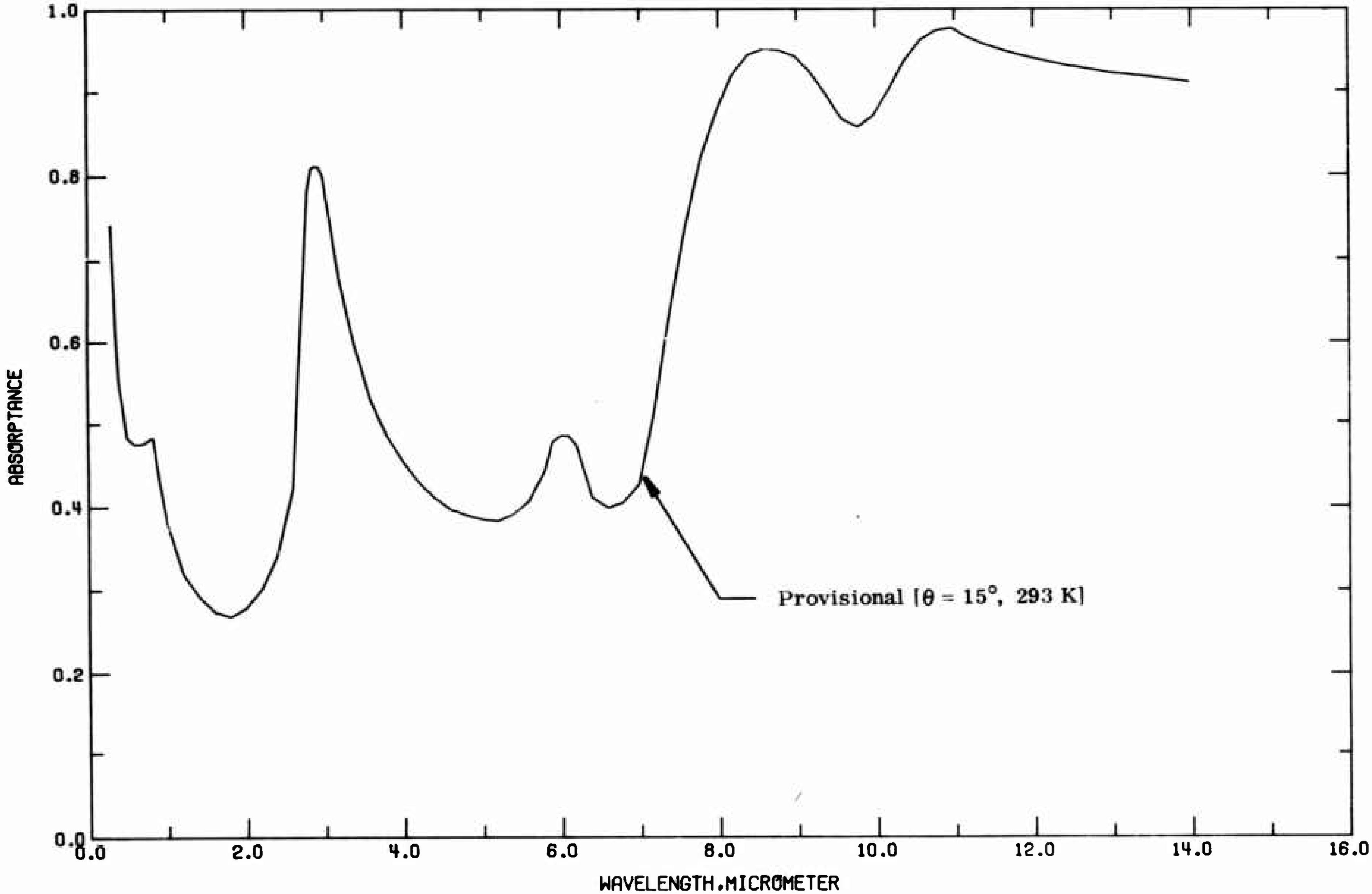


FIGURE 1-29. PROVISIONAL ANGULAR SPECTRAL ABSORPTANCE OF ANODIZED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

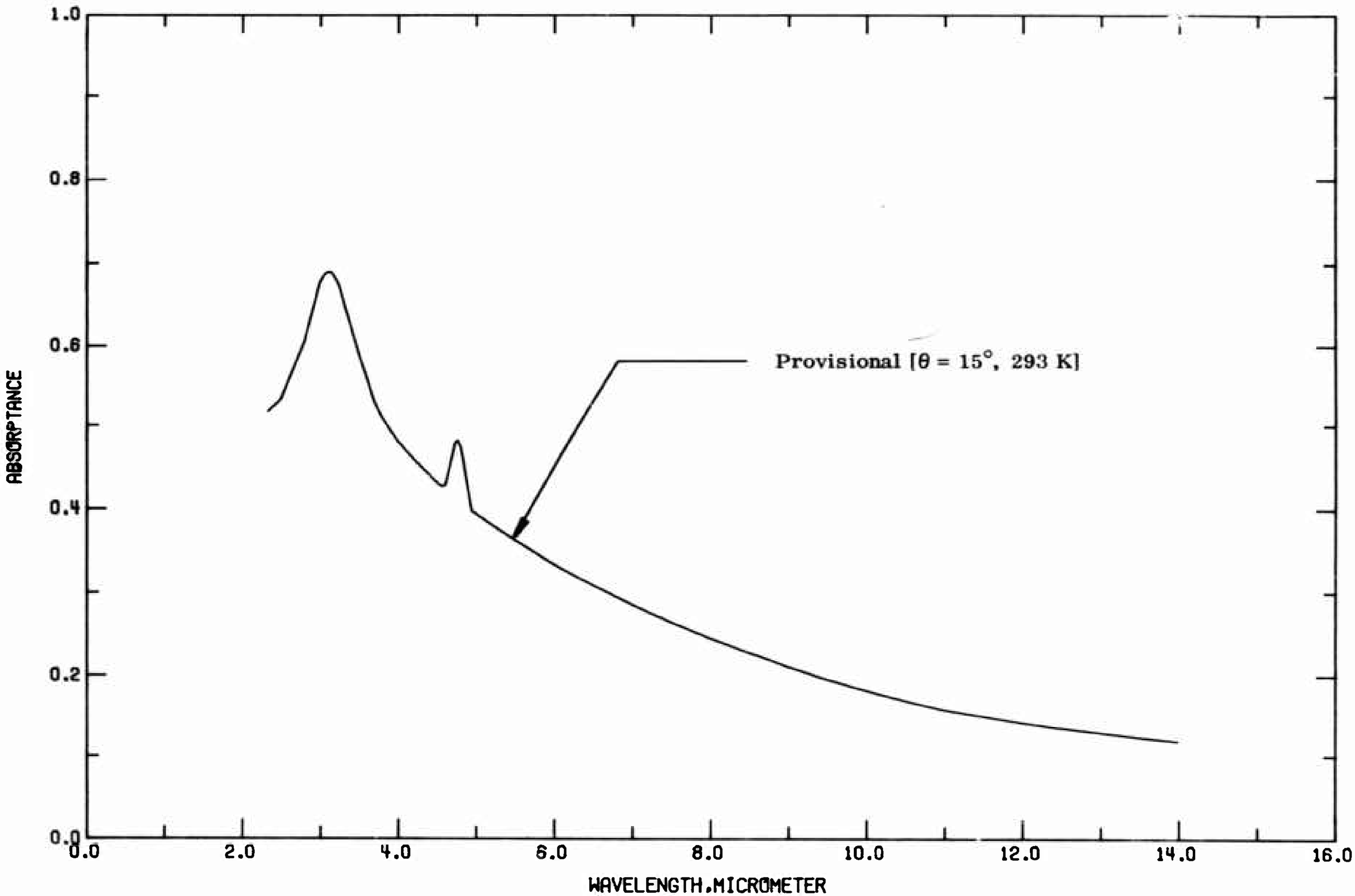


FIGURE 1-30. PROVISIONAL ANGULAR SPECTRAL ABSORPTANCE OF ALODINED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE)

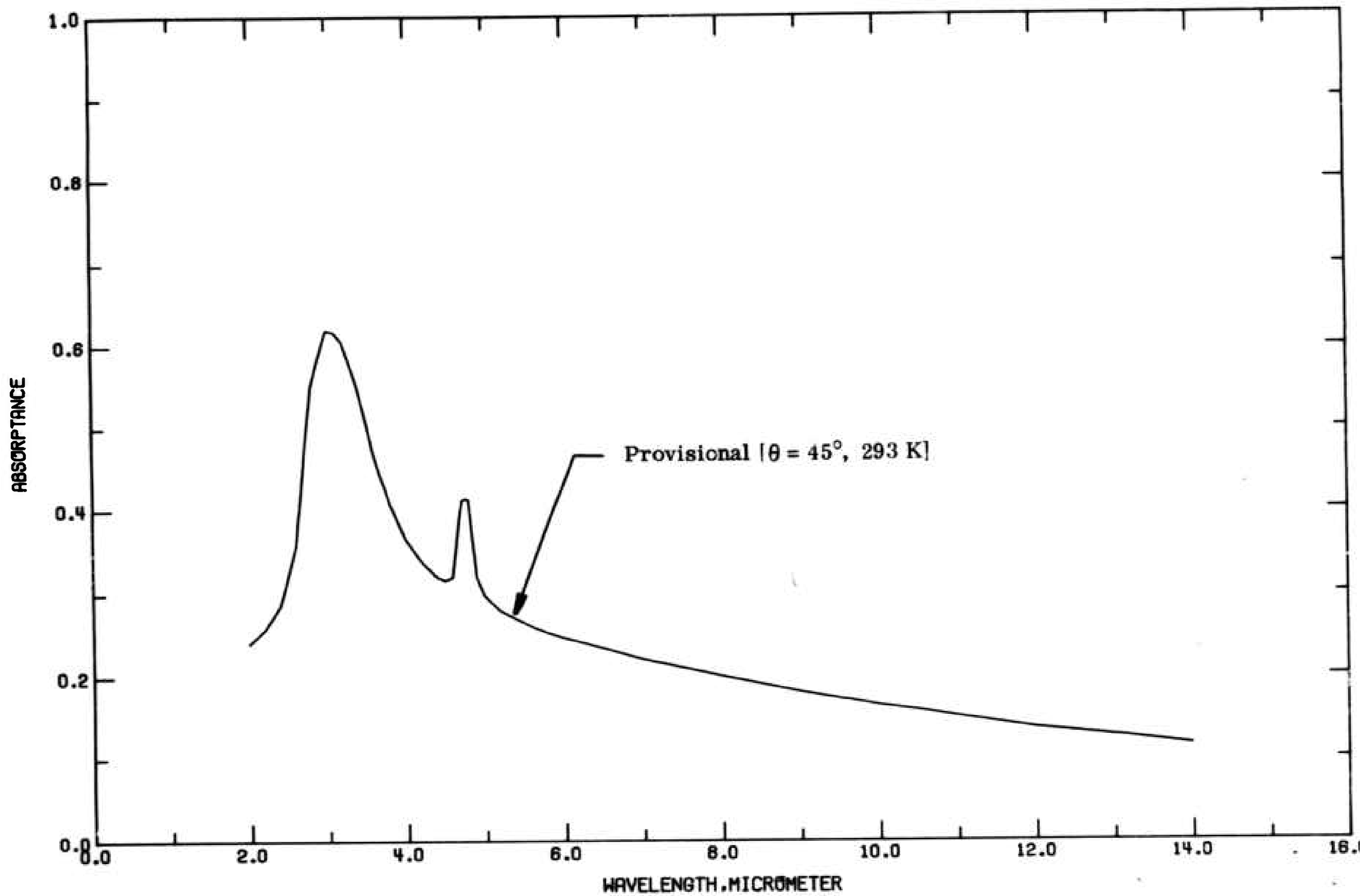


FIGURE 1-31. PROVISIONAL ANGULAR SPECTRAL ABSORPTANCE OF ALODINED ALUMINUM ALLOY 2024 (WAVELENGTH DEPENDENCE).

k. Transmittance

Although it is true that metals and alloys in the form of extremely thin films may be transparent for a wide wavelength range, they are opaque if the thickness is greater than several hundred angstroms.

As an aircraft/spacecraft structural material, this alloy is not used in the form of extremely thin films and therefore is opaque; that is, its transmittance is zero.

4.2. Aluminum Alloy 7075

Aluminum 7075, formerly known as aluminum alloy 75S is a wrought alloy with zinc as the principal alloying element. Its nominal composition (by weight) is: 5.5% Zn, 2.5% Mg, 1.5% Cu, 0.3% Cr, and Al balance [A00005]. Various properties and usage of this alloy is discussed in [T15906] and [A00005].

In the solution-heat treated condition, this alloy is designated as 7075-T6. It is among the highest strength aluminum alloy which is commonly used in the aircraft structural parts. This alloy is also available in clad state.

Some physical and mechanical properties [A00005] of this alloy are as follows:

Liquidus temperature: 911 K

Solidus temperature: 749 K

Density at 293 K: 2.80 g cm^{-3}

Room-temperature tensile (ultimate) strength: 23 kg mm^{-2} (for annealed alloy)
58 kg mm^{-2} (for 7075-T6)

Brinell hardness number: 60 (for annealed alloy)
(500 kg load, 10 mm ball) 150 (for 7075-T6)

a. Normal Spectral Emittance (Wavelength Dependence)

There are seven sets of experimental data available for the wavelength dependence (0.3-27 μm) of the normal spectral emittance of Aluminum Alloy 7075 under various surface conditions. These are tabulated in Table 2-3 and shown in Figure 2-2.

(1) Aluminum Alloy 7075

The recommended values tabulated in Table 2-1 and shown in Figure 2-1 for Aluminum Alloy 7075 with surface roughness of about 0.0005-0.0006 μm are primarily from the investigations of Schocken [T29202]. These are considered accurate to within ±15% over the entire wavelength range.

(2) Aluminum Alloy 7075-T6

The recommended values tabulated in Table 2-1 and shown in Figure 2-1 for Aluminum Alloy 7075-T6 rolled sheet were calculated from the normal spectral reflectance data (see Section 4.2.c).

TABLE 2-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

λ	ϵ	λ	ϵ
POLISHED ALLOY T = 323		ROLLED SHEET T = 293	
0.3	0.260	2.8	0.043
0.4	0.165	3.0	0.040
0.5	0.136	3.8	0.030
0.6	0.131	4.0	0.029
0.7	0.150	5.0	0.024
0.8	0.164	6.0	0.023
0.9	0.148	7.0	0.022
1.0	0.120	8.0	0.021
1.2	0.090	9.0	0.020
1.4	0.078	10.0	0.019
1.6	0.075	10.6	0.018
1.8	0.078	11.0	0.018
2.0	0.083	12.0	0.018
2.4	0.088	13.0	0.018
2.8	0.092	14.0	0.017
3.0	0.092	15.0	0.017
3.4	0.090		
3.8	0.082		
4.0	0.078		
4.5	0.070		
5.0	0.064		
6.0	0.054		
7.0	0.048		
8.0	0.046		
9.0	0.045		
10.0	0.045		
10.6	0.044		
11.0	0.043		
12.0	0.043		
13.0	0.043		
14.0	0.042		
15.0	0.042		

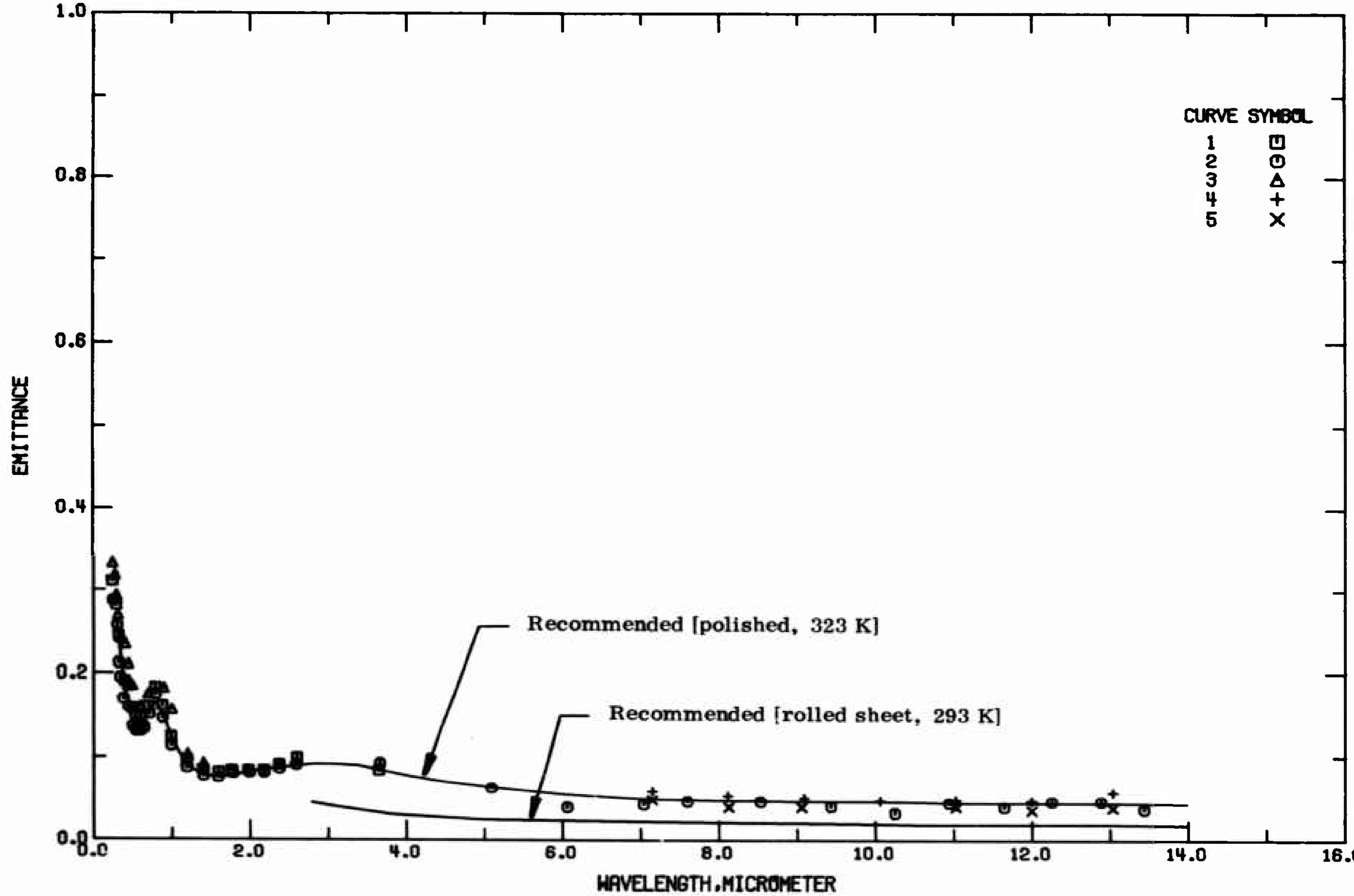


FIGURE 2-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE).

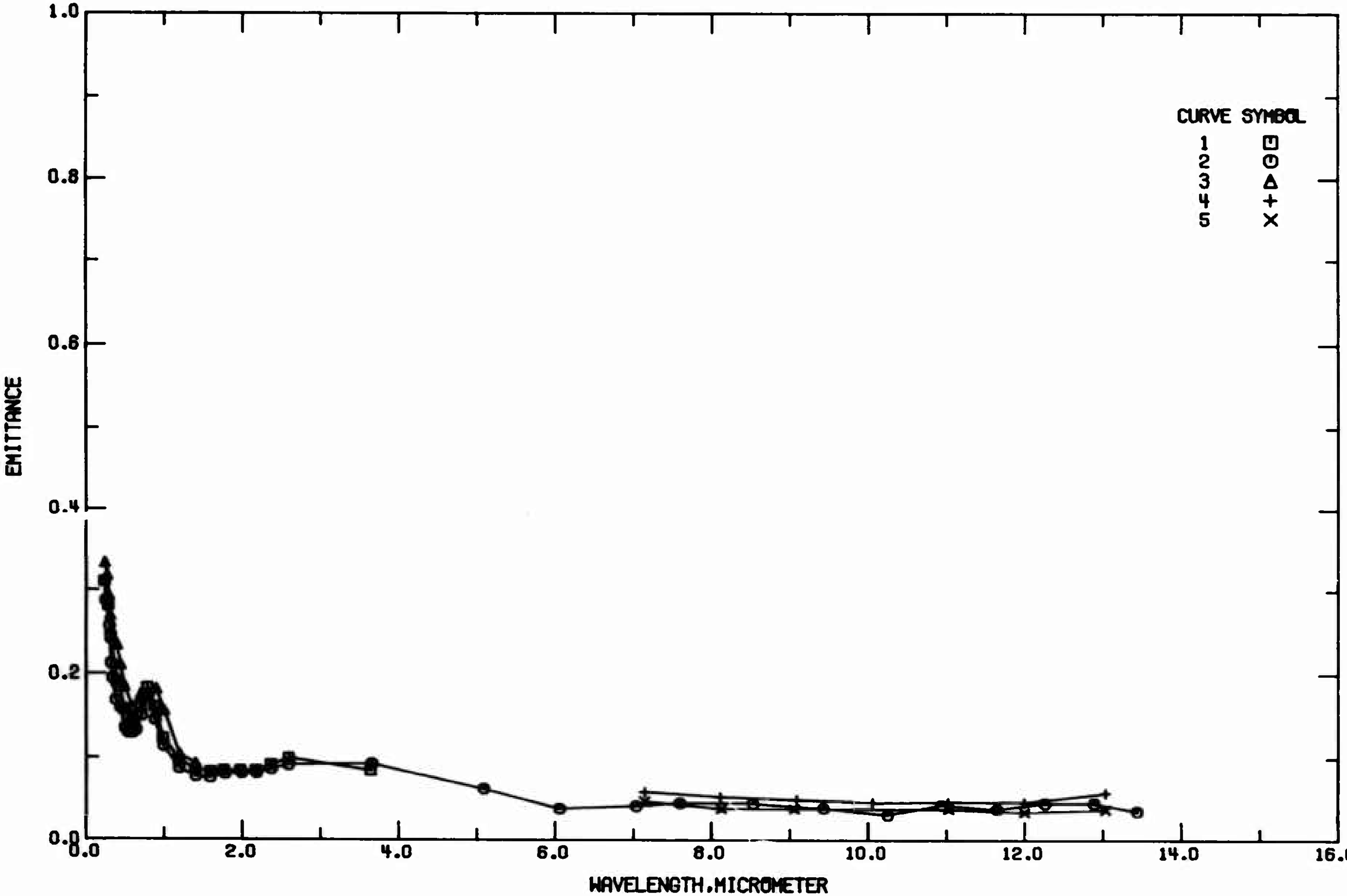


FIGURE 2-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE).

TABLE 2-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM ALLOY 7075 (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T29202	Schocken, K.	1963	0.29-3.65	323	Aluminum Alloy 7075 Specimen 1	Nominal composition; 5.6 Zn, 2.5 Mg, 1.6 Cu, 0.3 Cr, Al balance, surface roughness 3.2-4.4 microinches, measurements in nitrogen.
2	T29202	Schocken, K.	1963	0.24-26.9	323	Aluminum Alloy 7075 Specimen 3	Similar to the above specimen except surface roughness is 1.9-2.5 microinches.
3	T29202	Schocken, K.	1963	0.24-1.4	323	Aluminum Alloy 7075 Specimen 4	Similar to the above specimen except surface roughness is 3.2-4.5 microinches.
4	T20470	Weber, D.	1959	7.15-15.00	383	75 ST Aluminum	Specimen flat and smooth; reported error ± 50%.
5	T20470	Weber, D.	1959	7.15-15.05	323	75 ST Aluminum	Similar to the above specimen.

TABLE 2-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε
CURVE 1		CURVE	2(CONT.)	CURVE	3(CONT.)
T = 323.					
		0.88	0.144	0.34	0.240
0.24	0.310	0.99	0.113	0.40	0.233
0.29	0.280	1.19	0.087	0.44	0.210
0.32	0.242	1.40	0.077	0.49	0.185
0.40	0.190	1.59	0.075	0.60	0.159
0.44	0.184	1.78	0.080	0.70	0.175
0.49	0.157	1.99	0.081	0.90	0.132
0.54	0.148	2.18	0.081	1.00	0.155
0.60	0.145	2.37	0.086	1.20	0.103
0.70	0.159	2.59	0.091	1.40	0.093
0.79	0.183	3.66	0.093		
0.88	0.160	5.09	0.062	CURVE 4	
0.99	0.122	6.06	0.038	T = 383.	
1.19	0.097	7.04	0.041		
1.40	0.085	7.60	0.045	7.15	0.058
1.60	0.082	8.54	0.045	8.12	0.052
1.77	0.084	9.44	0.039	9.10	0.049
1.98	0.084	10.26	0.031	10.07	0.046
2.18	0.034	10.95	0.043	11.04	0.047
2.37	0.091	11.66	0.038	12.01	0.046
2.60	0.099	12.27	0.045	13.05	0.057
3.65	0.084	12.90	0.045	14.02	0.053
		13.45	0.035	15.00	0.078
CURVE 2		14.04	0.035		
T = 323.		14.04	0.043	CURVE 5	
		14.65	0.053	T = 323.	
0.24	0.310	16.19	0.029		
0.25	0.286	18.26	0.035	7.15	0.047
0.30	0.255	19.95	0.031	8.13	0.038
0.32	0.211	21.71	0.037	9.06	0.038
0.34	0.194	24.35	0.037	11.04	0.038
0.38	0.168	26.88	0.061	12.01	0.034
0.44	0.158			13.05	0.037
0.50	0.134	CURVE 3		14.02	0.037
0.54	0.129	T = 323.		15.00	0.044
0.59	0.129				
0.60	0.136	0.24	0.333		
0.64	0.132	0.27	0.318		
0.71	0.149	0.29	0.293		
0.79	0.174	0.31	0.268		

b. Angular Spectral Emittance (Wavelength Dependence)

There are six sets of experimental data available for the wavelength dependence (0.3-15 μm) of the angular spectral emittance of Aluminum Alloy 7075-T6 for an incidence angle, $\theta = 25°$. These values are tabulated in Table 2-6 and shown in Figure 2-4.

The recommended values tabulated in Table 2-4 and shown in Figure 2-3 for Aluminum Alloy 7075-T6 with surface roughness of about 0.0005-0.001 μm and the incident angle, $\theta = 25°$, are primarily from the investigation of Edwards and Catton [T38391]. These values are considered accurate to within ±15% over the entire wavelength range. The angular spectral reflectance values for the similar material, but sandblasted with silicon carbide, are considerably higher than the values reported in Table 2-4. It is worth noting that Edwards and Catton [T38391] consider their values as the normal spectral emittance rather than the angular spectral emittance. Therefore, tabulated values from Table 2-4 may be applicable for the normal spectral emittance.

TABLE 2-4. RECOMMENDED ANGULAR SPECTRAL EMITTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
POLISHED 7075-T6 ALLOY T = 300	
0.4	0.178
0.5	0.160
0.6	0.151
0.7	0.149
0.8	0.143
0.9	0.124
1.0	0.102
1.2	0.074
1.4	0.057
1.6	0.047
1.8	0.041
2.0	0.038
2.8	0.035
3.0	0.035
3.8	0.035
4.0	0.035
5.0	0.035
6.0	0.034
7.0	0.034
8.0	0.033
9.0	0.032
10.0	0.031
10.6	0.030
11.0	0.030
12.0	0.030
13.0	0.030
14.0	0.029
15.0	0.029

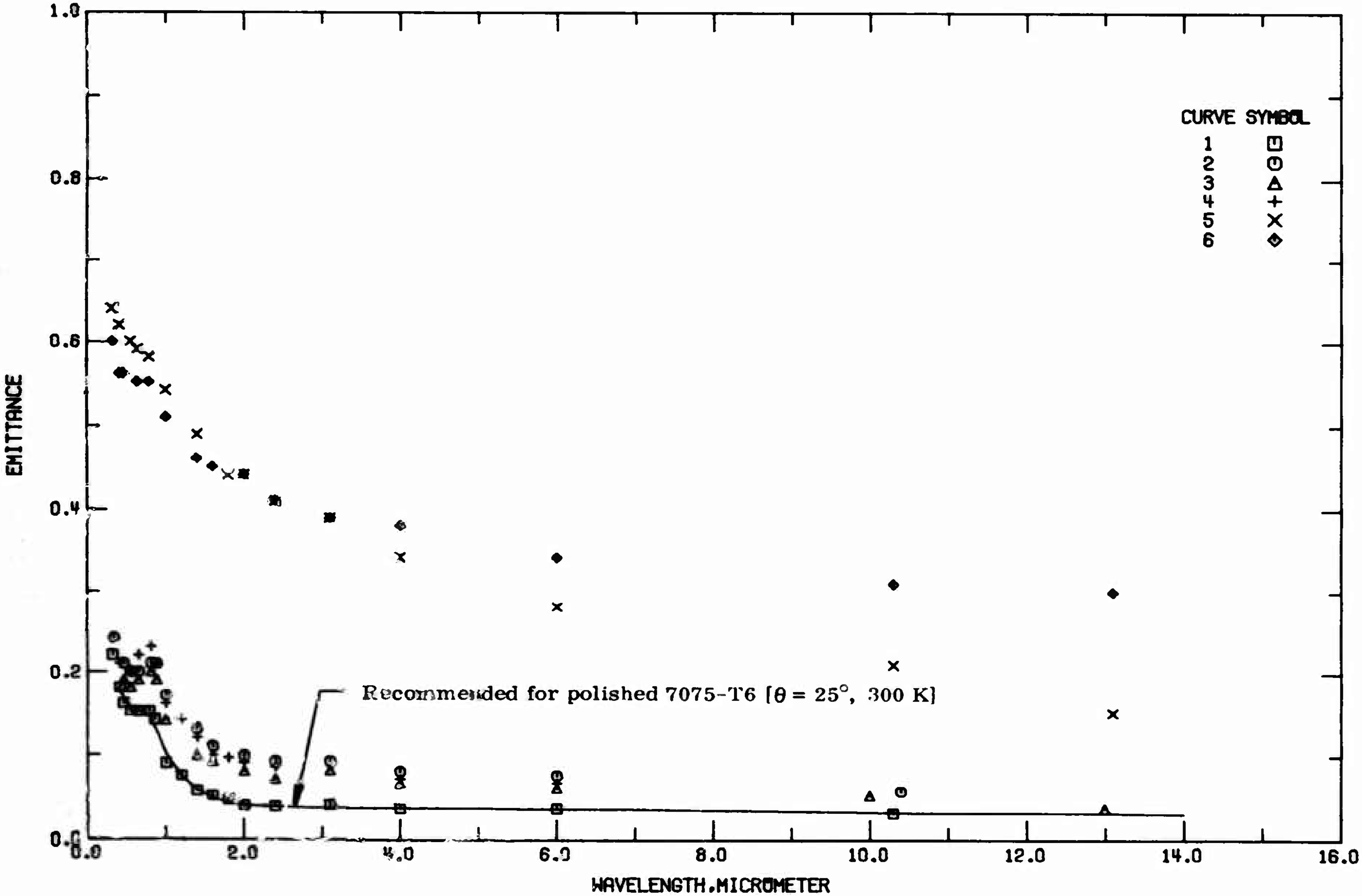


FIGURE 2-3. RECOMMENDED ANGULAR SPECTRAL EMITTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE).

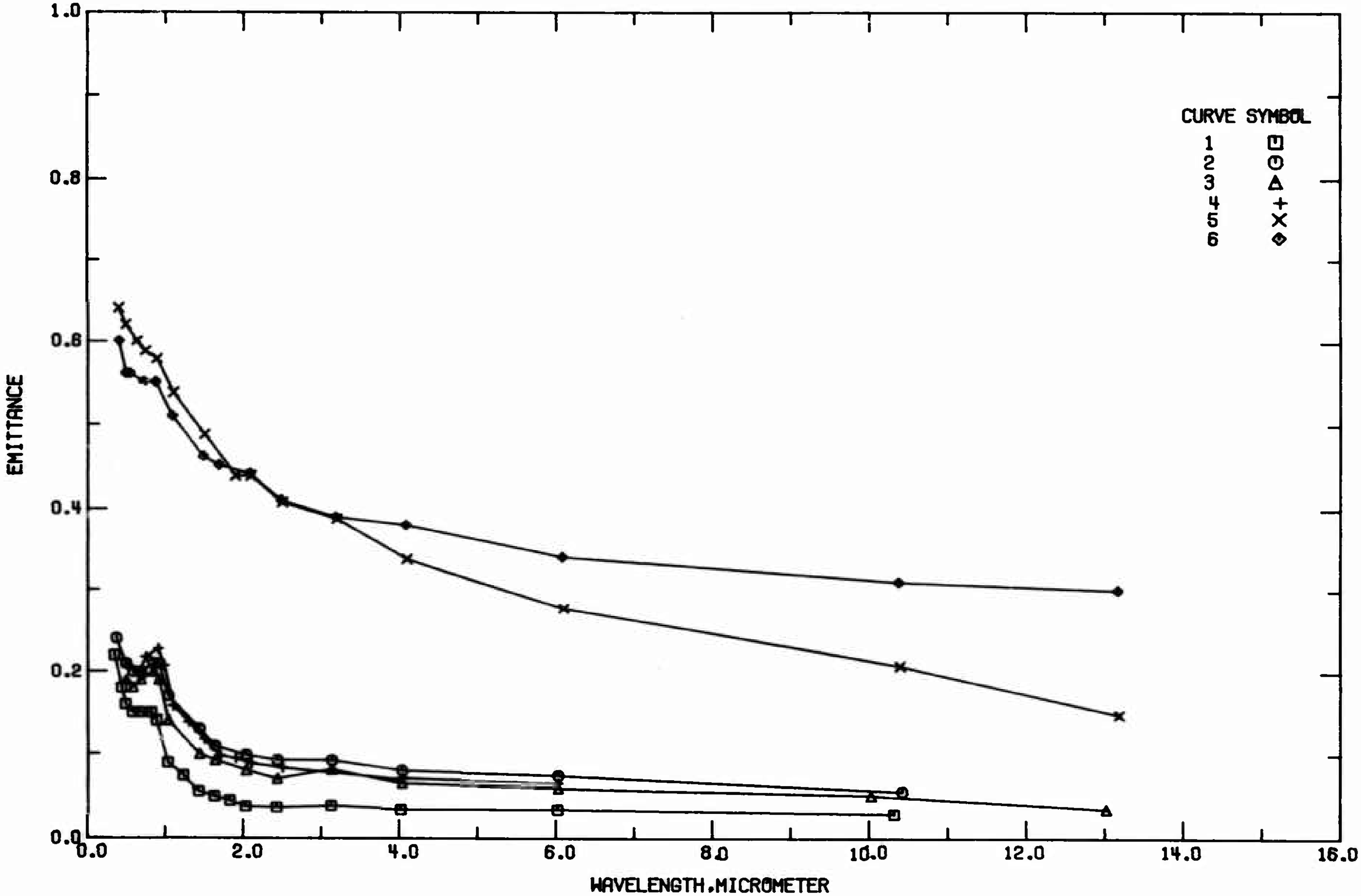


FIGURE 2-4. EXPERIMENTAL ANGULAR SPECTRAL EMITTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE).

TABLE 2-5. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL EMITTANCE OF ALUMINUM ALLOY 7075 (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T38391	Edwards, D.K. and Catton, I.	1965	0.32-15.0	306	7075-T6	Polished specimen; Rms rough; 2-4 microinches; θ=25°.
2	T38391	Edwards, D.K. and Catton, I.	1965	0.34-15.0	306	7075-T6	Similar to the above specimen except sanded; grit mesh number is 150; grit sieve opening is 104 μ; Rms roughness: 10-15 micro [illegible]hes in line, and 70-90 microinches across, θ=25°.
3	T38391	Edwards, D.K. and Catton, I.	1965	0.46-15.0	306	7075-T6	Similar to the above specimen except grit mesh number is 80; grit sieve opening is 175 μ; Rms roughness: 20-60 microinches in line and 150-170 microinches across; θ=25°.
4	T38391	Edwards, D.K. and Catton, I.	1965	0.41-15.0	306	7075-T6	Similar to the above specimen except grit mesh number is 40; grit sieve opening 42 μ; Rms roughness: 50-100 microinches in line and 270-300 microinches across; θ=25°.
5	T38391	Edwards, D.K. and Catton, I.	1965	0.32-15.0	306	7075-T6	Similar to the specimen in curve 6 except sandblasted with 250 mesh silicon carbide; Rms roughness 10-15 microinches; θ=25°.
6	T38391	Edwards, D.K. and Catton, I.	1965	0.32-15.0	306	7075-T6	Similar to the above specimen except sandblasted with 60 mesh Silicon Carbide; Rms roughness 250-300 microinches.

TABLE 2-6. EXPERIMENTAL ANGULAR SPECTRAL EMITTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

CURVE 1
T = 306.

λ	ε
0.32	0.22
0.41	0.18
0.46	0.16
0.55	0.15
0.64	0.15
0.79	0.15
0.86	0.14
1.0	0.090
1.2	0.075
1.4	0.056
1.6	0.050
1.8	0.045
2.0	0.038
2.4	0.037
3.1	0.039
4.0	0.035
6.0	0.035
10.3	0.030
15.0	0.030

CURVE 2
T = 306.

λ	ε
0.34	0.24
0.46	0.21
0.55	0.20
0.65	0.20
0.81	0.21
0.88	0.21
1.0	0.17
1.4	0.13
1.6	0.11
2.0	0.099
2.4	0.093
3.1	0.093
4.0	0.081
6.0	0.076
10.4	0.057
15.0	0.051

CURVE 3
T = 306.

λ	ε
0.46	0.19
0.55	0.18
0.65	0.19
0.81	0.20
0.88	0.19
1.0	0.14
1.4	0.10
1.6	0.093
2.0	0.081
2.4	0.071
3.1	0.082
4.0	0.066
6.0	0.061
10.0	0.052
13.0	0.036
15.0	0.036

CURVE 4
T = 306.

λ	ε
0.41	0.21
0.55	0.20
0.65	0.22
0.81	0.23
0.88	0.21
1.0	0.16
1.2	0.14
1.4	0.12
1.6	0.10
1.8	0.097
2.0	0.091
2.4	0.086
4.0	0.072
6.0	0.067
15.0	0.051

CURVE 5
T = 306.

λ	ε
0.32	0.64
0.41	0.62
0.55	0.60
0.64	0.59
0.79	0.58
1.0	0.54
1.4	0.49
1.8	0.44
2.0	0.44
2.4	0.41
3.1	0.39
4.0	0.34
6.0	0.28
10.3	0.21
13.1	0.15
15.8	0.13
17.1	0.12
19.2	0.11
21.1	0.11

CURVE 6
T = 306.

λ	ε
0.32	0.60
0.41	0.56
0.46	0.56
0.64	0.55
0.79	0.55
1.0	0.51
1.4	0.46
1.6	0.45
2.0	0.44
2.4	0.41
3.1	0.39
4.0	0.38
6.0	0.34
10.3	0.31
13.1	0.30
15.0	0.29

CURVE 6(CONT.)

λ	ε
17.1	0.29
19.2	0.28
21.1	0.27

c. Normal Spectral Reflectance (Wavelength Dependence)

There are no experimental data sets available for Aluminum Alloy 7075, however only one set of experimental data is available for the wavelength dependence (2.8-15.0 μm) of the normal spectral reflectance of Aluminum Alloy 7075-T6 alloy. This is tabulated in Table 2-9 and shown in Figure 2-6.

(1) Aluminum Alloy 7075

The recommended values tabulated in Table 2-7 and shown in Figure 2-5 are for Aluminum Alloy 7075 with surface roughness of about 0.0005-0.0006 μm. These values calculated from the normal spectral emittance data (see Section 4.2.b) are considered accurate to about ± 15% over the entire wavelength range.

(2) Aluminum Alloy 7075-T6

The recommended values tabulated in Table 2-7 and shown in Figure 2-5 for Aluminum Alloy 7075-T6 clad sheet are primarily from the investigation of Cunnington [A00027]. These values are considered accurate to within ± 15% over the entire temperature range.

TABLE 2-7. RECOMMENDED NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ
AL ALLOY 7075 POLISHED T = 323		AL ALLOY 7075-T6 ROLLED SHEET T = 293	
0.3	0.740	2.8	0.957
0.4	0.815	3.0	0.960
0.5	0.864	3.8	0.970
0.6	0.869	4.0	0.971
0.7	0.850	5.0	0.976
0.8	0.836	6.0	0.977
0.9	0.852	7.0	0.978
1.0	0.820	8.0	0.979
1.2	0.910	9.0	0.980
1.4	0.922	10.0	0.981
1.6	0.925	10.6	0.982
1.8	0.922	11.0	0.982
2.0	0.917	12.0	0.982
2.4	0.912	13.0	0.982
2.8	0.908	14.0	0.983
3.0	0.908	15.0	0.983
3.4	0.910		
3.8	0.918		
4.0	0.922		
4.5	0.930		
5.0	0.936		
6.0	0.946		
7.0	0.952		
8.0	0.954		
9.0	0.955		
10.0	0.955		
10.6	0.956		
11.0	0.957		
12.0	0.957		
13.0	0.957		
14.0	0.958		
15.0	0.958		

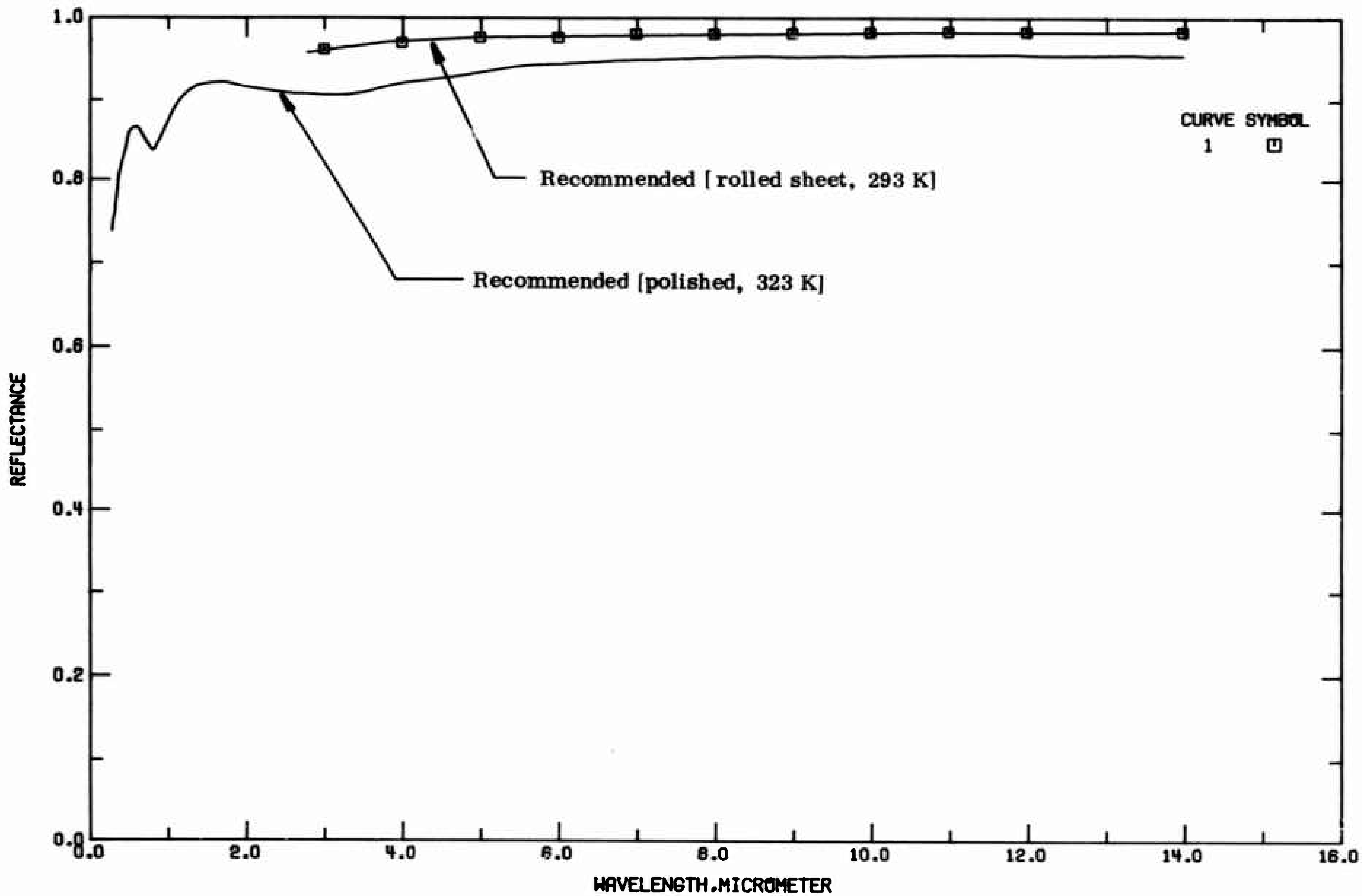


FIGURE 2-5. RECOMMENDED NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE).

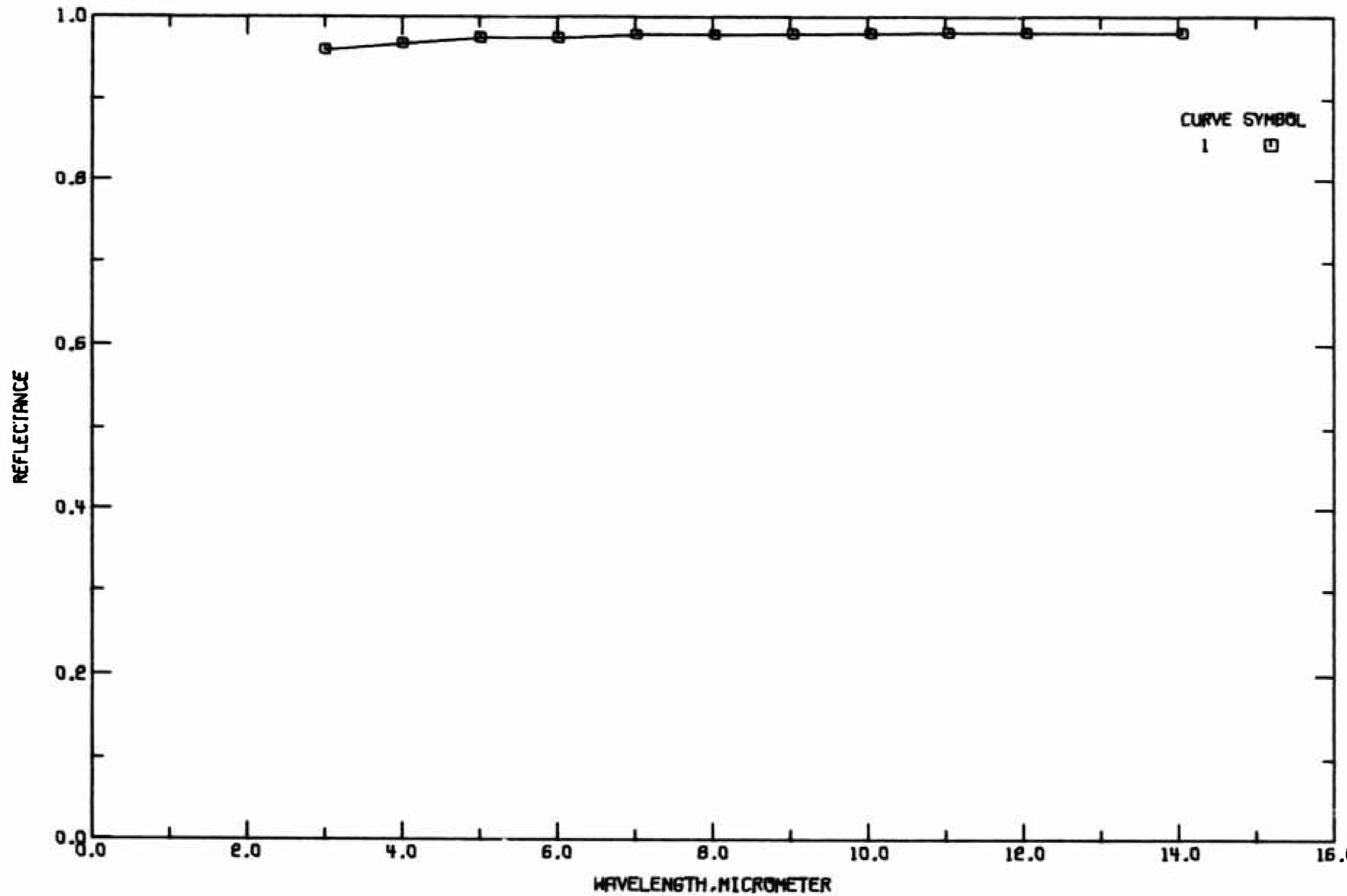


FIGURE 2-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY AL-7076 (WAVELENGTH DEPENDENCE).

TABLE 2-8. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 7075 (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00027	Cunnington, G.R.	1975	3-15	293	7075 T6	Rolled sheet.

TABLE 2-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 293.	
3.	0.961
4.	0.969
5.	0.976
6.	0.976
7.	0.980
8.	0.980
9.	0.981
10.	0.982
11.	0.983
12.	0.983
14.	0.983
15.	0.985
18.	0.986
20.	0.986
22.	0.986
24.	0.986

d. Angular Spectral Reflectance (Wavelength Dependence)

There are no experimental data available for this subproperty. The recommended values for Aluminum Alloy 7075-T6 with surface roughness 0.0005-0.001 μm and incidence angle, $\theta = 25^\circ$, are calculated from the recommended values of the angular spectral emittance (see Section 4.2.b). These values tabulated in Table 2-10 and shown in Figure 2-7 are considered accurate to within $\pm 15\%$ over the entire wavelength range. As discussed in Section 4.2.b, these values may be applicable for the normal spectral reflectance.

TABLE 2-10. RECOMMENDED ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
POLISHED 7075-T6 ALLOY T = 300	
0.4	0.822
0.5	0.840
0.6	0.849
0.7	0.851
0.8	0.857
0.9	0.876
1.0	0.892
1.2	0.926
1.4	0.943
1.6	0.953
1.8	0.959
2.0	0.962
2.8	0.965
3.0	0.965
3.8	0.965
4.0	0.965
5.0	0.965
6.0	0.966
7.0	0.966
8.0	0.967
9.0	0.968
10.0	0.969
10.6	0.970
11.0	0.970
12.0	0.970
13.0	0.970
14.0	0.971
15.0	0.971

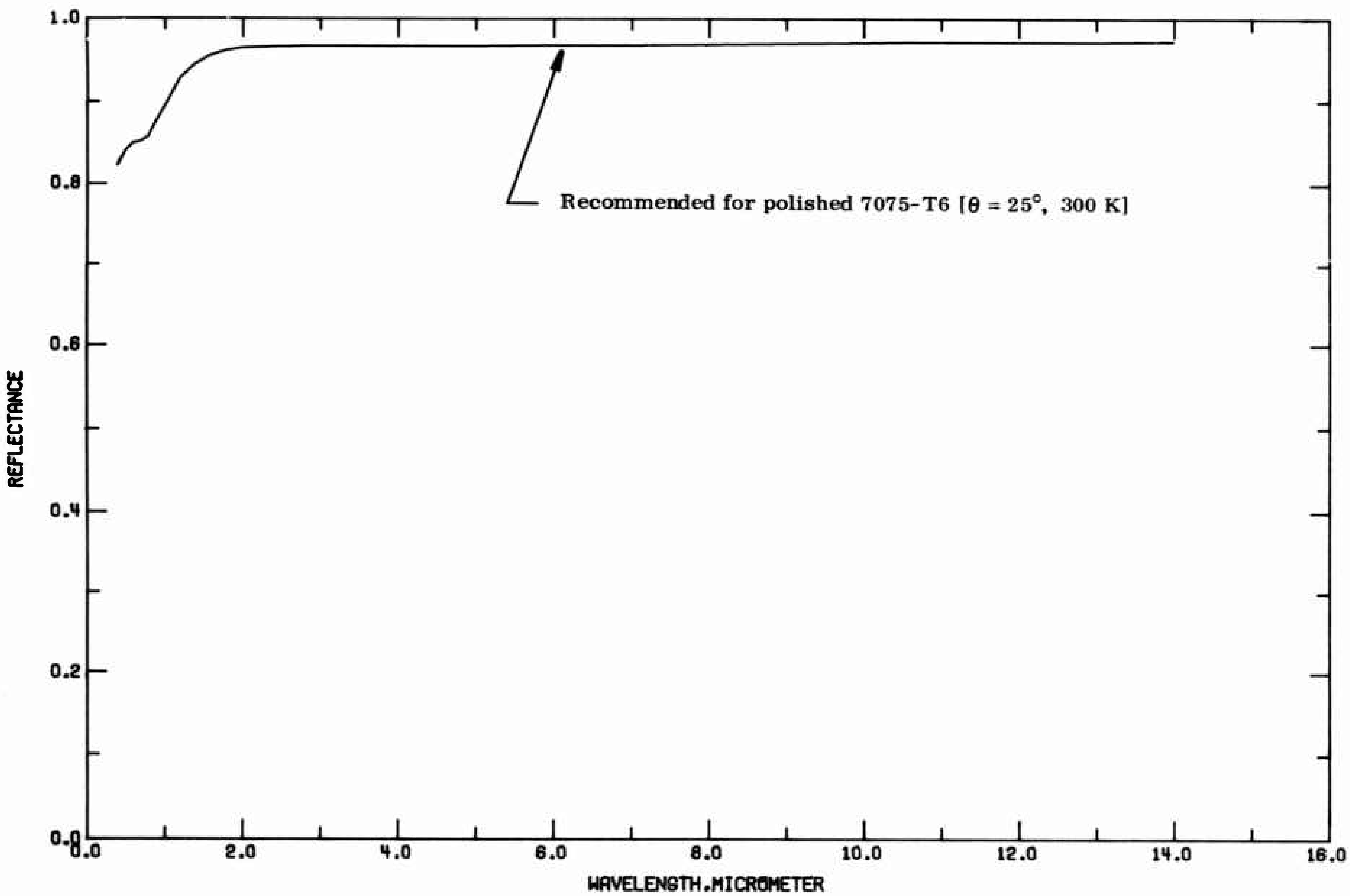


FIGURE 2-7. RECOMMENDED ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE).

e. Normal Spectral Absorptance (Wavelength Dependence)

There are no experimental data available for this subproperty.

(1) Aluminum Alloy 7075

The recommended values tabulated in Table 2-11 and shown in Figure 2-8 are for Aluminum Alloy 7075 with surface roughness of about 0.0005-0.0006 μm. These values calculated from the recommended values for the normal spectral emittance tabulated in Table 2-1 are considered accurate to about ± 15% over the entire wavelength range.

(2) Aluminum Alloy 7075-T6

The recommended values tabulated in Table 2-11 and shown in Figure 2-8 are for Aluminum Alloy 7075-T6 clad sheet. These values calculated from the normal spectral emittance data tabulated in Table 2-1 are considered accurate to about ± 15% over the entire wavelength range.

TABLE 2-11. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α)

λ	α	λ	α
POLISHED ALLOY T = 323		ROLLED SHEET T = 293	
0.3	0.260	2.8	0.043
0.4	0.185	3.0	0.040
0.5	0.136	3.8	0.030
0.6	0.131	4.0	0.029
0.7	0.150	5.0	0.024
0.8	0.164	6.0	0.023
0.9	0.148	7.0	0.022
1.0	0.120	8.0	0.021
1.2	0.090	9.0	0.020
1.4	0.078	10.0	0.019
1.6	0.075	10.6	0.018
1.8	0.078	11.0	0.018
2.0	0.083	12.0	0.018
2.4	0.088	13.0	0.018
2.8	0.092	14.0	0.017
3.0	0.092	15.0	0.017
3.4	0.090		
3.8	0.082		
4.0	0.078		
4.5	0.070		
5.0	0.064		
6.0	0.054		
7.0	0.048		
8.0	0.046		
9.0	0.045		
10.0	0.045		
10.6	0.044		
11.0	0.043		
12.0	0.043		
13.0	0.043		
14.0	0.042		
15.0	0.042		

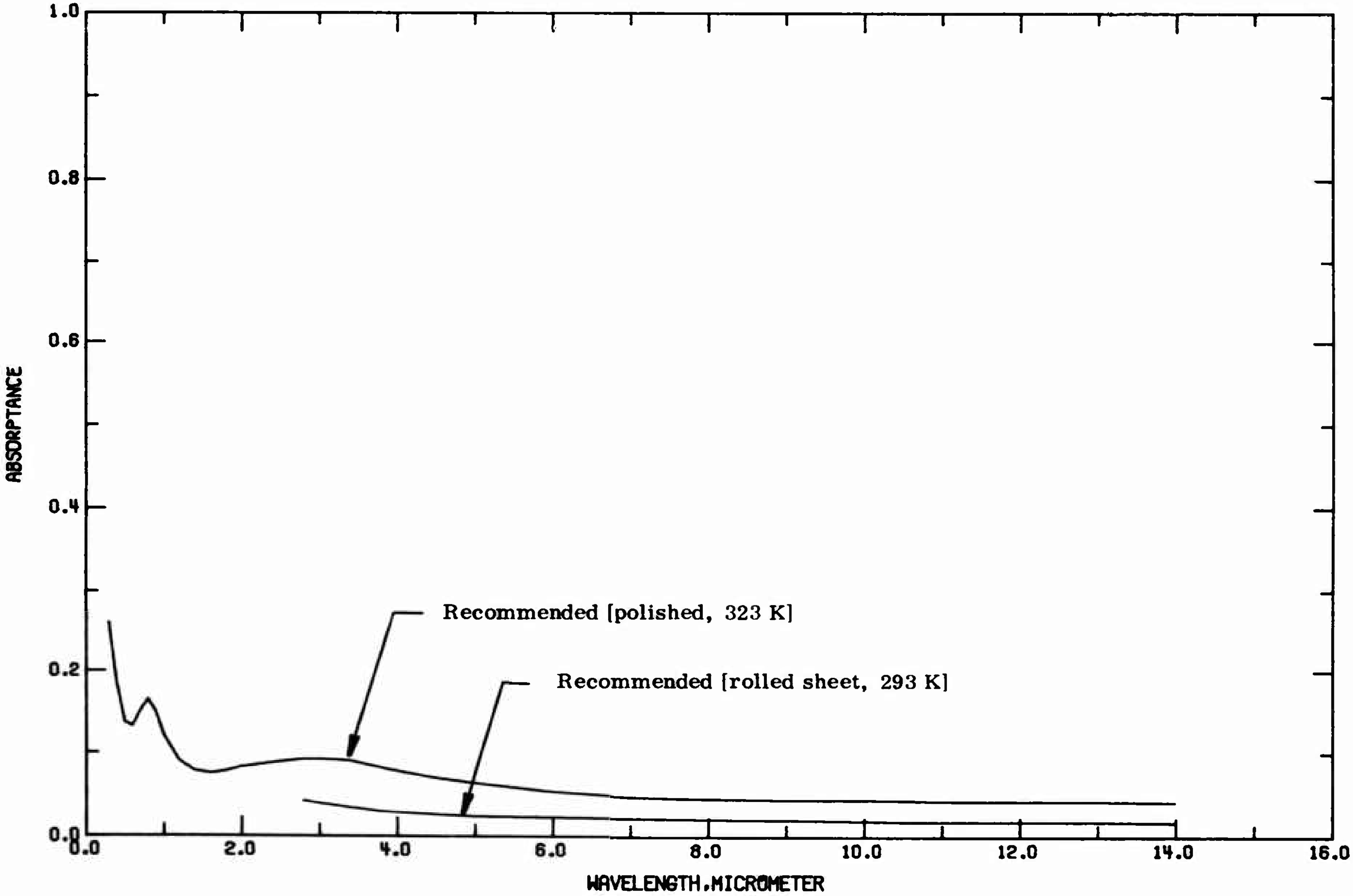


FIGURE 2-8. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE).

f. Angular Spectral Absorptance (Wavelength Dependence)

There are no experimental data available for this subproperty. The recommended values tabulated in Table 2-12 and shown in Figure 2-9 are for Aluminum Alloy 7075-T6 with surface roughness of about 0.0005-0.001 μm, and incidence angle, $\theta = 25^\circ$. These values calculated from the recommended values tabulated in Table 2-4 are considered accurate to about $\pm 15\%$ over the entire wavelength range. As discussed in Section 4.2.b these values may be applicable for the normal spectral absorptance.

TABLE 2-12. RECOMMENDED ANGULAR SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α
POLISHED 7075-T6 ALLOY T = 300	
0.4	0.178
0.5	0.160
0.6	0.151
0.7	0.149
0.8	0.143
0.9	0.124
1.0	0.102
1.2	0.074
1.4	0.057
1.6	0.047
1.8	0.041
2.0	0.038
2.6	0.035
3.0	0.035
3.8	0.035
4.0	0.035
5.0	0.035
6.0	0.034
7.0	0.034
8.0	0.033
9.0	0.032
10.0	0.031
10.6	0.030
11.0	0.030
12.0	0.030
13.0	0.030
14.0	0.029
15.0	0.029

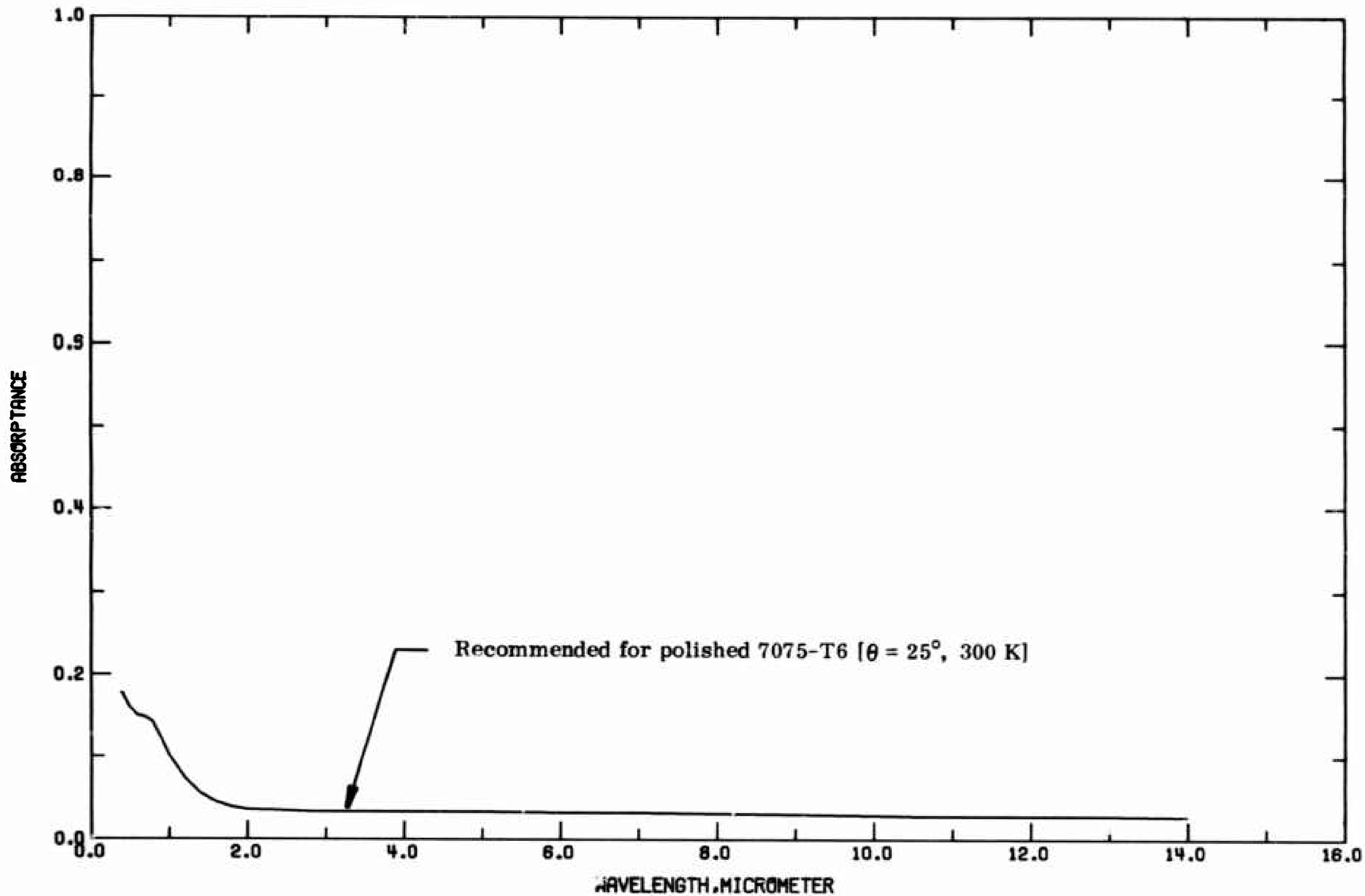


FIGURE 2-9. RECOMMENDED ANGULAR SPECTRAL ABSORPTANCE OF ALUMINUM ALLOY 7075 (WAVELENGTH DEPENDENCE).

g. Transmittance

Although it is true that metals and alloys in the form of extremely thin films may be transparent for a wide wavelength range, they are opaque if the thickness is greater than several hundred angstroms.

As an aircraft/spacecraft structural material, this alloy is not used in the form of extremely thin films and therefore is opaque; that is, its transmittance is zero.

4.3. AISI 304 Stainless Steel

The family of steel known as "stainless steel" covers an exceptionally wide range. About 35-40 different combinations of ingredients have been used by various manufacturers. Primarily all stainless steels have a base alloy of Fe and Cr. The nominal composition of s.s. 304 is (18-20%) Cr, (8-12%) Ni, 2% Mn, 1% Si, 0.08% C, and Fe balance. The composition of s.s. 304-L type is essentially the same except the composition of carbon is lowered to 0.03%.

Chromium, when added in excess of 10%, makes alloy heat and corrosion resistance. Other elements are added to obtain special characteristics. The most important of these in the case of stainless steel is nickel which increases its corrosion resistance and workability of the alloy. This addition causes a structural change which is known as austenitic which makes the alloy nonhardenable and nonmagnetic. It is possible to weld AISI 304 stainless in moderate thickness without subsequent heat treatment to restore corrosion resistance, whereas 304-L variety, due to its low carbon content, has lower hazard of carbide precipitation after welding or annealing.

Various properties and uses of this alloy are discussed in detail in [A00005]. Some of the physical properties can be summarized as follows:

Density:	7.9 g cm^{-3}
Melting range:	1670-1727 K
Electrical resistivity: at room temperature	72 $\mu\Omega$ cm
Modulus of elasticity in tension:	28 x 10^6 psi
Modulus of elasticity in torsion:	12.5 x 10^6 psi

a. Normal Spectral Emittance (Wavelength Dependence)

There are 31 sets of experimental data available for the wavelength dependence (0.20-27 μm) of the normal spectral emittance of AISI 304 Stainless Steel for oxidized and anodized surfaces covering the temperature range from room temperature to 1273 K. These are tabulated in Table 3-3 and shown in Figure 3-2.

(1) Polished AISI 304 Stainless Steel

The recommended values at 293 K tabulated in Table 3-1 and shown in Figure 3-1 are for polished and unoxidized surfaces are primarily from the investigations of Rolling and Funai [T47998, T29202]. These values are considered accurate to within ±15% over the entire wavelength range.

(2) Oxidized AISI 304 Stainless Steel

The typical values at 1273 K tabulated in Table 3-1 and shown in Figure 3-1 are for polished and oxidized surfaces of a sample heated in air for about six hours at 1273 K. These values, primarily from the investigations of Blau, et al. [T16606] are considered accurate to about ±30% over the entire wavelength range.

TABLE 3-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε
POLISHED NOT OXIDIZED T = 293		POLISHED NOT OXIDIZED T = 293 (CONT.)		POLISHED OXIDIZED T = 1273	
0.22	0.572	13.50	0.077	2.00	0.768B†
0.25	0.532	14.00	0.076	2.50	0.769B
0.30	0.392			2.80	0.762B
0.32	0.372			3.00	0.754B
0.40	0.392			3.50	0.729B
0.50	0.302			3.80	0.708B
0.80	0.272			4.00	0.690B
1.00	0.252			4.50	0.664B
1.50	0.206			5.00	0.650B
1.80	0.172			5.50	0.680B
2.00	0.167			6.00	0.717B
2.20	0.164			6.50	0.744B
2.40	0.162			7.00	0.760B
2.50	0.172			7.50	0.770B
2.60	0.180			8.00	0.776B
2.80	0.176			8.50	0.780B
3.00	0.172			9.00	0.781B
3.50	0.165			9.50	0.765B
3.80	0.160			10.00	0.746B
4.00	0.156			10.60	0.689B
4.50	0.148			11.00	0.648B
5.00	0.140			11.50	0.600B
5.50	0.134			12.00	0.554B
6.00	0.128			12.50	0.502B
6.50	0.121			13.00	0.456B
7.00	0.116			13.50	0.424B
7.50	0.111			14.00	0.402B
8.00	0.107				
8.50	0.102				
9.00	0.098				
9.50	0.096				
10.00	0.092				
10.50	0.089				
10.60	0.088				
11.00	0.086				
11.50	0.083				
12.00	0.081				
12.50	0.080				
13.00	0.079				

† VALUE FOLLOWED BY A "B" IS TYPICAL.

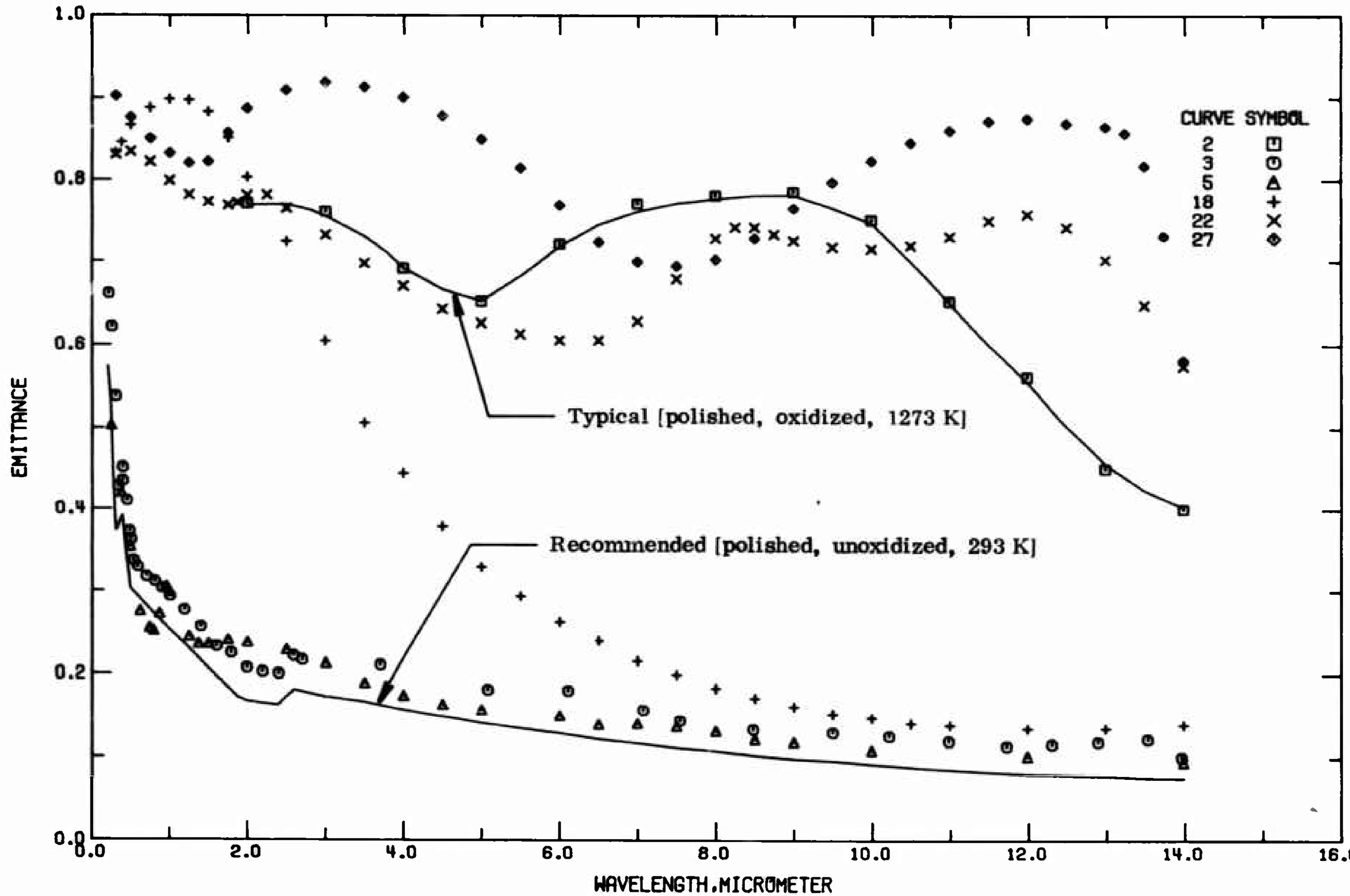


FIGURE 3-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE).

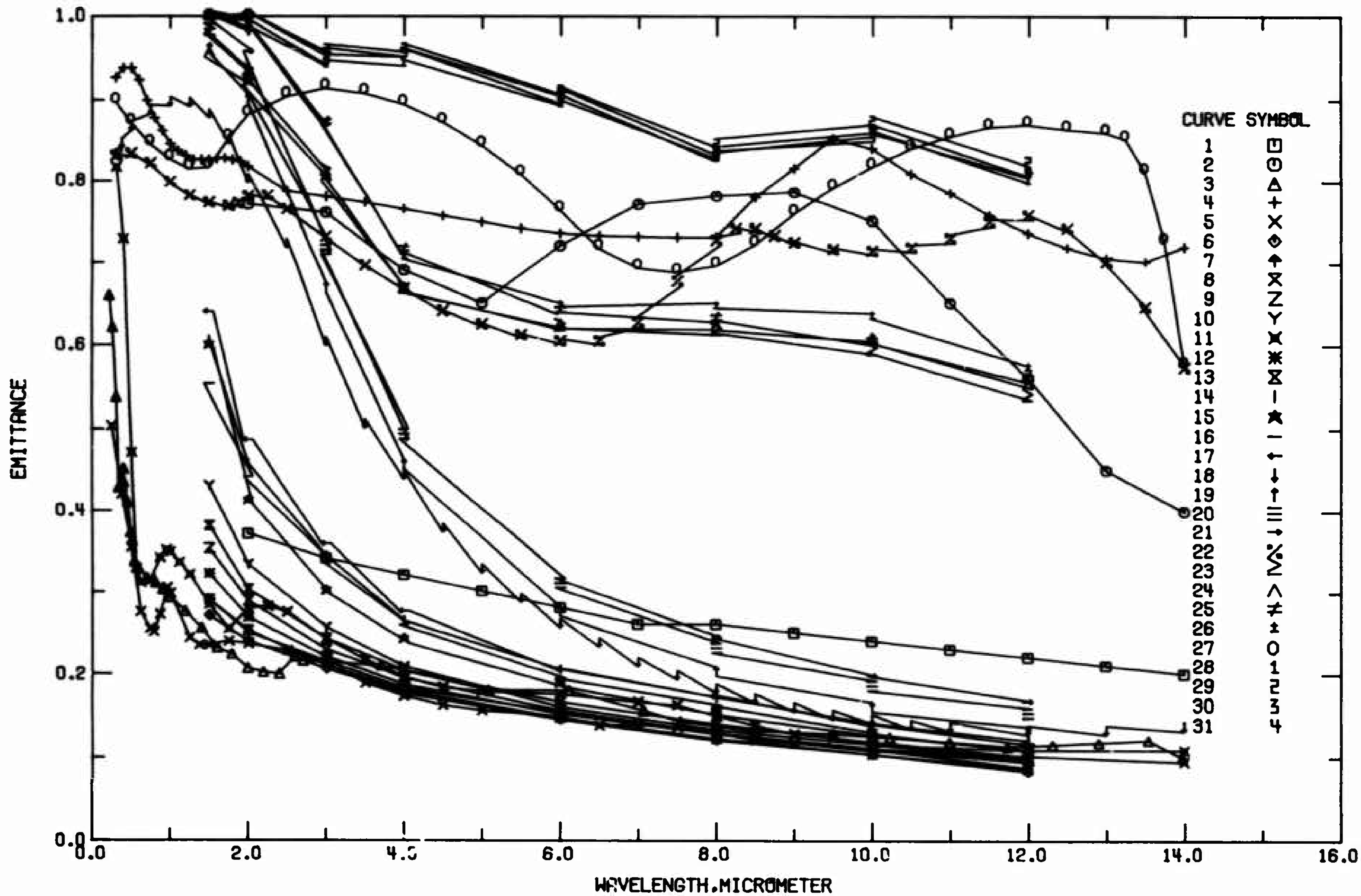


FIGURE 3-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE).

TABLE 3-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF AISI 304 STAINLESS STEEL (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T16606	Blau, H.H., March, J.B., Martin, W.S., Jasperse, J.R., and Chaffee, E.	1960	2.0-14.0	873		Nominal composition: 18.00-20.00 Cr, 8.00-12.00 Ni; 2.00 max Mn, 1.00 max Si, 0.08 max C, Fe balance; oxidized in air for 3 hr at 873 K; measured in air; $\theta' \sim 0°$.
2	T16606	Blau, H.H., et al.	1960	2.0-14.0	1273		Different sample, same as above specimen and conditions except oxidized in air for 6 hr at 1273 K.
3	T29202	NASA Technical Note No. D-1523	1963	0.20-27.00	323		Nominal composition: 18.00-20.00 Cr, 8.00-12.00 Ni; 2.00 max Mn, 1.00 max Si, 0.08 max C, Fe balance; surface roughness 0.75 micro-inches (center line avg); measured in nitrogen; computed from $\epsilon = 1 - R(2\pi, 5°)$; author indicated that slight error in transition region of 2.5 μ to 6.5 μ, deviation around 6 μ can be attributed to water vapor absorption, apparent rise at 24 to 27 μ due to scattered light; $\theta' \sim 5°$.
4	T70314	Conrardy, W.P.	1963	0.3-21.0	1255		Chemical composition furnished by the supplier, 0.08 C, 1.0 Si, 2.0 Mn, 8-11 Ni, 18-20 Cr and Fe balance; disk specimen machined from rod stock obtained from Ducommun Metals and Supply Company; oxide formed by heating in air at 1255 K for 2 hr; stablized after 30 days at 922 K.
5	T47998	Rolling, R.E. and Funai, A.I.	1967	0.25-18.9	300	1S	Sample 2 x 8 x 0.015 in. obtained with type 2B (bright, annealed) surface finish; 18.37 Cr, 8.89 Ni, 1.80 Mn, 0.50 Si, 0.058 C, 0.025 P, 0.007 S, and Te balance; electropolished and cleaned using the following procedure: Step 1, soak 5 min. in $Na_4P_2O_7$ solution (60 g/liter) at 130 F, Step 2, electropolish for 20 min in a H_3Po_4-H_2SO_4 solution at 80 F, Step 3, rinse with distilled water, Step 4, dip in solution of nitric acid (100 ml per liter) and sodium dichromate (20 g per liter), Step 5, rinse and dry, rms roughness 0.33 μm; not oxidized surface.
6	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	811	1S-2	Similar to the above specimen, first temperature cycle, time at this temperature 45 min.
7	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	955	1S-2	Similar to the above specimen, first temperature cycle, time at this temperature 35 min.
8	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	807	1S-2	Similar to the above specimen, second temperature cycle, surface appeared to be unoxidized at start of this cycle, time at this temperature 3 hr 15 min.
9	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	946	1S-2	Similar to the above specimen, time at this temperature 3 hr 15 min.
10	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	948	1S-2	Similar to the above specimen, time at this temperature 3 hr 50 min.
11	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	300	2S	Similar to the above specimen except oxidized for 1/2 hr at 600 C in wet hydrogen furnace, average weight gain 2.1 $\mu g/cm^2$, approximate film thickness 0.015 μm based on weight gain data and assumption of uniform film of Fe_3O_4 with average density of 5.2 g/cm^3, gold color of interference film, test pressure 4 x 10^{-6} torr.
12	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	810	2S	Similar to the above specimen, first temperature cycle for 2 hr.
13	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	952	2S	Similar to the above specimen, at this temperature for 3 hr 20 min.
14	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	1061	2S	Similar to the above specimen, at this temperature for 6 hr.

TABLE 3-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF AISI 304 STAINLESS STEEL (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
15	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	1087	2S	Similar to the above specimen.
16	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	803	2S	Similar to the above specimen except second temperature cycle, at this temperature for 2 hr 10 min, color of oxide film changed from gold to silver-gray.
17	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	940	2S	Similar to the above specimen, at this temperature for 35 min.
18	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	300	3S	Similar to the above specimen except oxidation temperature at 800 C for 30 min, average weight gain 24.3 $\mu g/cm^2$, approximate film thickness 0.170 μm, purple color of oxide film, test pressure 2.5×10^{-6} torr.
19	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	807	3S	Similar to the above specimen except at this temperature for 2 hr.
20	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	953	3S	Similar to the above specimen except at this temperature for 3 hr 15 min.
21	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	1090	3S	Similar to the above specimen except at this temperature for 5 hr 30 min, instability of the oxide film observed.
22	T47998	Rolling, R.E. and Funai, A.I.	1967	0.31-18.9	300	4S	Similar to the above specimen except oxidation temperature at 1000 C for 30 min, average weight gain 135.7 $\mu g/cm^2$, approximate film thickness 0.95 μ, dull gray color of oxide film; test pressure 4.5×10^{-6} torr.
23	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	818	4S	Similar to the above specimen except first temperature cycle, at this temperature for 1 hr 40 min.
24	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	957	4S	Similar to the above specimen except at this temperature for 5 hr.
25	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	811	4S	Similar to the above specimen except second temperature cycle, at this temperature for 40 min.
26	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	949	4S	Similar to the above specimen.
27	T47998	Rolling, R.E. and Funai, A.I.	1967	0.31-19	300	5S	Similar to the above specimen except oxidation temperature at 1000 C for 90 min, average weight gain 200 $\mu g/cm^2$, approximate film thickness 1.40 μm, dark brownish gray color of oxide film, test pressure 3.5 to 5×10^{-6} torr.
28	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	809	5S	Similar to the above specimen except first temperature cycle, at this temperature for 3 hr 15 min.
29	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	950	5S	Similar to the above specimen except at this temperature for 3 hr 30 min.
30	T47998	Rolling, R.E. and Funai, A.I.	1967	1.5-12	814	5S	Similar to the above specimen except second temperature cycle, at this temperature for 30 min.
31	T47998	Rolling, R.E. and	1967	1.5-12	952	5S	Similar to the above specimen except at this temperature for 45 min.

TABLE 3-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 1	
T = 873.	
2.0	0.370
3.0	0.340
4.0	0.320
5.0	0.300
6.0	0.280
7.0	0.260
8.0	0.260
9.0	0.250
10.0	0.240
11.0	0.230
12.0	0.220
13.0	0.210
14.0	0.200
CURVE 2	
T = 1273.	
2.0	0.770
3.0	0.760
4.0	0.690
5.0	0.650
6.0	0.720
7.0	0.773
8.0	0.780
9.0	0.785
10.0	0.750
11.0	0.650
12.0	0.560
13.0	0.450
14.0	0.400
CURVE 3	
T = 323.	
0.22	0.659
0.26	0.621
0.31	0.537
0.34	0.428
0.40	0.451

λ	ε
CURVE 3 (CONT.)	
0.40	0.435
0.45	0.410
0.49	0.372
0.51	0.362
0.54	0.337
0.59	0.329
0.70	0.317
0.81	0.311
0.90	0.303
1.00	0.293
1.19	0.276
1.40	0.256
1.60	0.232
1.79	0.224
1.99	0.207
2.19	0.202
2.40	0.200
2.59	0.221
2.70	0.216
3.70	0.210
5.08	0.181
6.11	0.180
7.07	0.157
7.54	0.144
8.48	0.133
9.50	0.129
10.22	0.125
10.99	0.119
11.73	0.113
12.31	0.115
12.90	0.118
13.54	0.121
13.98	0.103
16.23	0.091
18.26	0.091
21.76	0.093
24.34	0.097
26.92	0.095

λ	ε
CURVE 4	
T = 1255.	
0.3	0.925
0.4	0.936
0.5	0.936
0.6	0.922
0.7	0.898
0.8	0.876
0.9	0.860
1.0	0.844
1.1	0.836
1.2	0.830
1.3	0.825
1.4	0.825
1.5	0.825
1.6	0.826
1.7	0.827
1.8	0.825
1.9	0.823
2.0	0.817
2.5	0.786
3.0	0.779
3.5	0.772
4.0	0.764
4.5	0.756
5.0	0.749
5.5	0.741
6.0	0.735
6.5	0.732
7.0	0.731
7.5	0.730
8.0	0.730
8.5	0.779
9.0	0.815
9.5	0.851
10.0	0.839
10.5	0.808
11.0	0.784
11.5	0.757
12.0	0.735
12.5	0.718

λ	ε
CURVE 4 (CONT.)	
13.0	0.705
13.5	0.701
14.0	0.719
14.5	0.730
15.0	0.732
15.5	0.732
16.0	0.743
16.5	0.756
17.0	0.801
17.5	0.776
18.0	0.737
18.5	0.725
19.0	0.782
19.5	0.815
20.0	0.830
20.5	0.810
21.0	0.766
CURVE 5	
T = 300.	
0.25	0.503
0.38	0.420
0.50	0.354
0.62	0.275
0.74	0.255
0.79	0.251
0.87	0.272
0.96	0.305
1.00	0.298
1.25	0.244
1.37	0.235
1.50	0.235
1.75	0.240
2.00	0.237
2.50	0.228
3.00	0.212
3.50	0.189
4.00	0.174
4.50	0.163

λ	ε
CURVE 5 (CONT.)	
5.00	0.157
6.00	0.150
6.50	0.139
7.00	0.140
7.59	0.137
8.00	0.131
8.50	0.121
9.00	0.118
10.00	0.108
12.00	0.102
14.00	0.095
14.50	0.094
15.00	0.089
15.50	0.088
16.00	0.095
17.00	0.093
18.00	0.090
18.96	0.089
CURVE 6	
T = 811.	
1.5	0.271
2.0	0.240
3.0	0.206
4.0	0.177
6.0	0.146
8.0	0.121
10.0	0.104
12.0	0.084
CURVE 7	
T = 955.	
1.5	0.290
2.0	0.251
3.0	0.215
4.0	0.183
6.0	0.155
8.0	0.130

λ	ε
CURVE 7 (CONT.)	
10.0	0.110
12.0	0.095
CURVE 8	
T = 807.	
1.5	0.290
2.0	0.253
3.0	0.210
4.0	0.180
6.0	0.148
8.0	0.123
10.0	0.104
12.0	0.087
CURVE 9	
T = 946.	
1.5	0.353
2.0	0.289
3.0	0.230
4.0	0.195
6.0	0.157
8.0	0.130
10.0	0.111
12.0	0.098
CURVE 10	
T = 948.	
1.5	0.431
2.0	0.334
3.0	0.257
4.0	0.209
6.0	0.161
8.0	0.134
10.0	0.116
12.0	0.097

TABLE 3-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 11	
T = 300.	
0.31	0.816
0.40	0.728
0.50	0.471
0.56	0.329
0.62	0.311
0.75	0.314
0.87	0.342
0.95	0.351
1.00	0.349
1.12	0.336
1.25	0.321
1.50	0.284
1.75	0.255
2.00	0.279
2.25	0.282
2.50	0.275
3.00	0.243
3.50	0.217
4.00	0.196
4.50	0.184
5.00	0.179
6.00	0.176
7.00	0.167
7.50	0.163
8.00	0.151
8.50	0.139
9.00	0.129
9.50	0.125
10.00	0.115
12.00	0.109
14.00	0.109
16.00	0.109
16.50	0.114
17.00	0.118
17.50	0.115
18.00	0.112
18.96	0.108

λ	ε
CURVE 12	
T = 810.	
1.5	0.322
2.0	0.269
3.0	0.221
4.0	0.187
6.0	0.153
8.0	0.129
10.0	0.110
12.0	0.088
CURVE 13	
T = 952.	
1.5	0.381
2.0	0.303
3.0	0.243
4.0	0.204
6.0	0.167
8.0	0.141
10.0	0.119
12.0	0.101
CURVE 14	
T = 1081.	
1.5	0.606
2.0	0.458
3.0	0.344
4.0	0.265
6.0	0.206
8.0	0.173
10.0	0.142
12.0	0.121
CURVE 15	
T = 1087.	
1.5	0.600
2.0	0.413
3.0	0.302

λ	ε
CURVE 15(CONT.)	
4.0	0.243
6.0	0.190
8.0	0.157
10.0	0.132
12.0	0.114
CURVE 16	
T = 803.	
1.5	0.553
2.0	0.442
3.0	0.338
4.0	0.260
6.0	0.195
8.0	0.163
10.0	0.130
12.0	0.107
CURVE 17	
T = 940.	
1.5	0.640
2.0	0.487
3.0	0.359
4.0	0.277
6.0	0.206
8.0	0.174
10.0	0.140
12.0	0.117
CURVE 18	
T = 300.	
0.31	0.832
0.38	0.845
0.50	0.866
0.75	0.887
1.00	0.897
1.25	0.896
1.50	0.882

λ	ε
CURVE 18(CONT.)	
1.75	0.850
2.00	0.802
2.50	0.723
3.00	0.604
3.50	0.506
4.00	0.444
4.50	0.378
5.00	0.329
5.50	0.293
6.00	0.262
6.50	0.239
7.00	0.215
7.50	0.199
8.00	0.183
8.50	0.171
9.00	0.161
9.50	0.152
10.00	0.147
10.50	0.140
11.00	0.138
12.00	0.134
13.00	0.134
14.00	0.138
14.50	0.146
15.00	0.157
15.50	0.157
16.00	0.151
17.00	0.151
18.00	0.164
18.96	0.179
CURVE 19	
T = 807.	
1.5	0.960
2.0	0.900
3.0	0.669
4.0	0.457
6.0	0.276
8.0	0.263

λ	ε
CURVE 19(CONT.)	
10.0	0.161
12.0	0.132
CURVE 20	
T = 953.	
1.5	0.990
2.0	0.923
3.0	0.715
4.0	0.494
6.0	0.311
8.0	0.232
10.0	0.186
12.0	0.154
CURVE 21	
T = 1090.	
1.5	1.000
2.0	0.956
3.0	0.714
4.0	0.488
6.0	0.317
8.0	0.245
10.0	0.198
12.0	0.168
CURVE 22	
T = 300.	
0.31	0.830
0.50	0.833
0.75	0.821
1.00	0.798
1.25	0.781
1.50	0.772
1.75	0.768
1.87	0.771
2.00	0.780
2.25	0.781

λ	ε
CURVE 22(CONT.)	
2.50	0.764
3.00	0.731
3.50	0.696
4.00	0.668
4.50	0.641
5.00	0.625
5.50	0.612
6.00	0.605
6.50	0.605
7.00	0.627
7.50	0.677
8.00	0.727
8.25	0.741
8.50	0.741
8.75	0.732
9.00	0.724
9.50	0.716
10.00	0.714
10.50	0.718
11.00	0.729
11.50	0.749
12.00	0.757
12.50	0.741
13.00	0.701
13.50	0.646
14.00	0.573
14.50	0.447
15.00	0.358
15.50	0.294
16.00	0.268
16.50	0.295
17.00	0.376
17.50	0.483
17.75	0.456
18.00	0.376
18.25	0.356
18.50	0.346
18.75	0.342
18.94	0.343

TABLE 3-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

CURVE 23
T = 818.

λ	ε
1.5	0.979
2.0	0.930
3.0	0.809
4.0	0.665
6.0	0.620
8.0	0.615
10.0	0.591
12.0	0.536

CURVE 24
T = 957.

λ	ε
1.5	0.955
2.0	0.921
3.0	0.805
4.0	0.669
6.0	0.625
8.0	0.624
10.0	0.609
12.0	0.553

CURVE 25
T = 811.

λ	ε
1.5	1.000
2.0	1.000
3.0	0.872
4.0	0.717
6.0	0.642
8.0	0.633
10.0	0.606
12.0	0.561

CURVE 26
T = 949.

λ	ε
1.5	1.000
2.0	0.998
3.0	0.870

CURVE 26 (CONT.)

λ	ε
4.0	0.707
6.0	0.648
8.0	0.647
10.0	0.635
12.0	0.573

CURVE 27
T = 300.

λ	ε
0.31	0.901
0.50	0.875
0.75	0.849
1.00	0.831
1.25	0.819
1.50	0.821
1.75	0.856
2.00	0.886
2.50	0.908
3.00	0.918
3.50	0.912
4.00	0.899
4.50	0.877
5.00	0.848
5.50	0.813
6.00	0.768
6.50	0.722
7.00	0.698
7.50	0.693
8.00	0.701
8.50	0.727
9.00	0.764
9.50	0.796
10.00	0.822
10.50	0.844
11.00	0.859
11.50	0.871
12.00	0.874
12.50	0.868
13.00	0.864
13.25	0.856

CURVE 27 (CONT.)

λ	ε
13.50	0.816
13.75	0.730
14.00	0.580
14.25	0.447
14.50	0.387
14.75	0.348
15.00	0.334
15.50	0.333
15.75	0.347
16.00	0.352
16.25	0.357
16.50	0.374
16.75	0.426
17.00	0.511
17.30	0.638
17.42	0.638
17.50	0.629
17.59	0.362
17.69	0.343
17.79	0.350
18.00	0.376
18.25	0.406
18.50	0.421
18.75	0.428
19.00	0.424

CURVE 28
T = 809.

λ	ε
1.5	1.000
2.0	0.986
3.0	0.943
4.0	0.944
6.0	0.897
8.0	0.831
10.0	0.859
12.0	0.802

CURVE 29
T = 950.

λ	ε
1.5	1.000
2.0	1.000
3.0	0.960
4.0	0.961
6.0	0.910
8.0	0.845
10.0	0.874
12.0	0.823

CURVE 30
T = 814.

λ	ε
1.5	1.000
2.0	0.992
3.0	0.947
4.0	0.955
6.0	0.901
8.0	0.830
10.0	0.853
12.0	0.810

CURVE 31
T = 952.

λ	ε
1.5	1.000
2.0	1.000
3.0	0.955
4.0	0.955
6.0	0.908
8.0	0.835
10.0	0.864
12.0	0.810

b. Normal Spectral Emittance (Temperature Dependence)

There is no experimental data available for this property. The provisional values for the polished surface, tabulated in Table 3-4 and shown in Figure 3-3, for 3.8 μ and 10.6 μ, covering the temperature range from room temperature to the melting point, were calculated by using the Kirchhoff law, i.e., $\epsilon_\lambda = \alpha_\lambda$. Data for α_λ are available in Section 4.3.g. These are considered accurate to within $\pm 20\%$ over the entire temperature range.

TABLE 3-4. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF AISI 304 STAINLESS STEEL (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ	T	ϵ
POLISHED		POLISHED	
λ = 3.8		λ = 10.6	
293.	0.137	293.	0.088
300.	0.138	300.	0.089
400.	0.143	400.	0.093
500.	0.148	500.	0.097
600.	0.154	600.	0.100
700.	0.158	700.	0.103
800.	0.165	800.	0.106
900.	0.170	900.	0.110
1000.	0.176	1000.	0.113
1100.	0.180	1100.	0.117
1200.	0.186	1200.	0.120
1300.	0.192	1300.	0.123
1400.	0.196	1400.	0.127
1500.	0.202	1500.	0.129
1600.	0.207	1600.	0.132
1700.	0.212	1700.	0.136
1727.	0.213	1727.	0.136

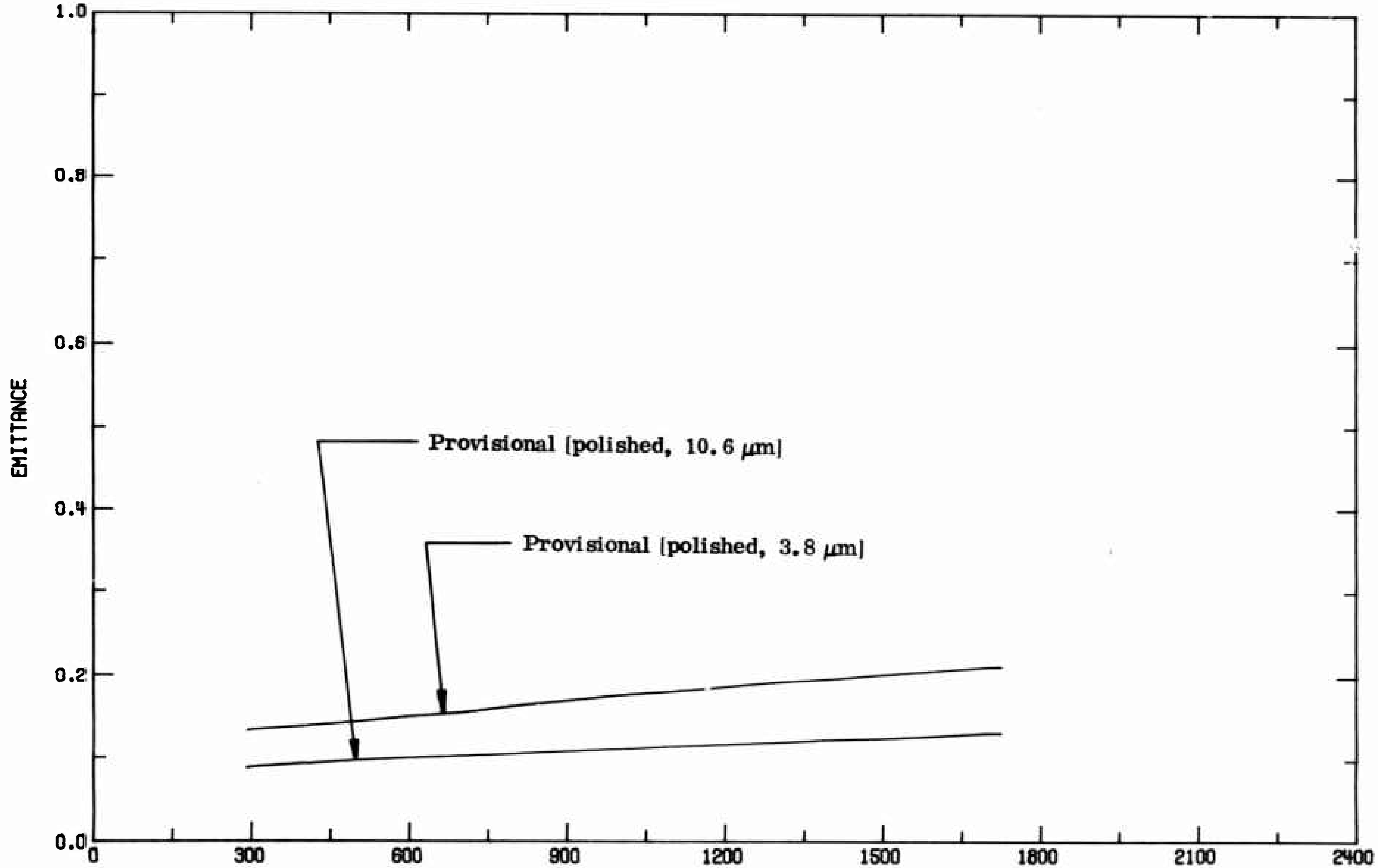


FIGURE 3-3. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF AISI 304 STAINLESS STEEL (TEMPERATURE DEPENDENCE).

c. Normal Spectral Reflectance (Wavelength Dependence)

There are seven experimental data sets available for the wavelength dependence (0.97-295.9 μm) of the normal spectral reflectance of AISI 304 Stainless Steel from 77 K to room temperature. These are tabulated in Table 3-7 and shown in Figure 3-5.

The recommended values at 293 K, tabulated in Table 3-5 and shown in Figure 3-4, are for polished and unoxidized surfaces. These values, primarily from the investigations of Leigh [T33512] and Stockham [T45583], and the recommended values for the normal spectral emittance shown in Table 3-1 are considered accurate to within ±15% over the entire wavelength range.

The typical values at 1273 K, tabulated in Table 3-5 and shown in Figure 3-4, are for polished and oxidized surfaces. These values were calculated by using the Kirchhoff law, $\rho_\lambda = 1 - \alpha_\lambda = 1 - \epsilon_\lambda$, where the values for the normal spectral emittance are shown in Table 3-1. These values are considered accurate to about ±30% over the entire wavelength range.

TABLE 3-5. RECOMMENDED NORMAL SPECTRAL REFLECTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ
POLISHED		POLISHED		POLISHED OXIDIZED	
T = 293		T = 293 (CONT.)		T = 1273	
0.22	0.428	13.50	0.923	2.00	0.2328†
0.25	0.468	14.00	0.924	2.50	0.2318
0.30	0.698			2.80	0.2388
0.32	0.628			3.00	0.2468
0.40	0.608			3.50	0.2718
0.50	0.698			3.80	0.2928
0.80	0.728			4.00	0.3108
1.00	0.748			4.50	0.3368
1.50	0.794			5.00	0.3508
1.88	0.828			5.50	0.3208
2.00	0.833			6.00	0.2838
2.20	0.836			6.50	0.2568
2.40	0.838			7.00	0.2408
2.50	0.828			7.50	0.2308
2.60	0.820			8.00	0.2248
2.80	0.824			8.50	0.2208
3.00	0.828			9.00	0.2198
3.50	0.834			9.50	0.2358
3.80	0.840			10.00	0.2548
4.00	0.846			10.60	0.3118
4.50	0.852			11.00	0.3528
5.00	0.860			11.50	0.4008
5.50	0.866			12.00	0.4468
6.00	0.872			12.50	0.4988
6.50	0.879			13.00	0.5448
7.00	0.884			13.50	0.5768
7.50	0.889			14.00	0.5988
8.00	0.893				
8.50	0.898				
9.00	0.902				
9.50	0.904				
10.00	0.908				
10.50	0.911				
10.60	0.912				
11.00	0.914				
11.50	0.917				
12.80	0.919				
12.50	0.920				
13.00	0.921				

† VALUE FOLLOWED BY A "B" IS TYPICAL.

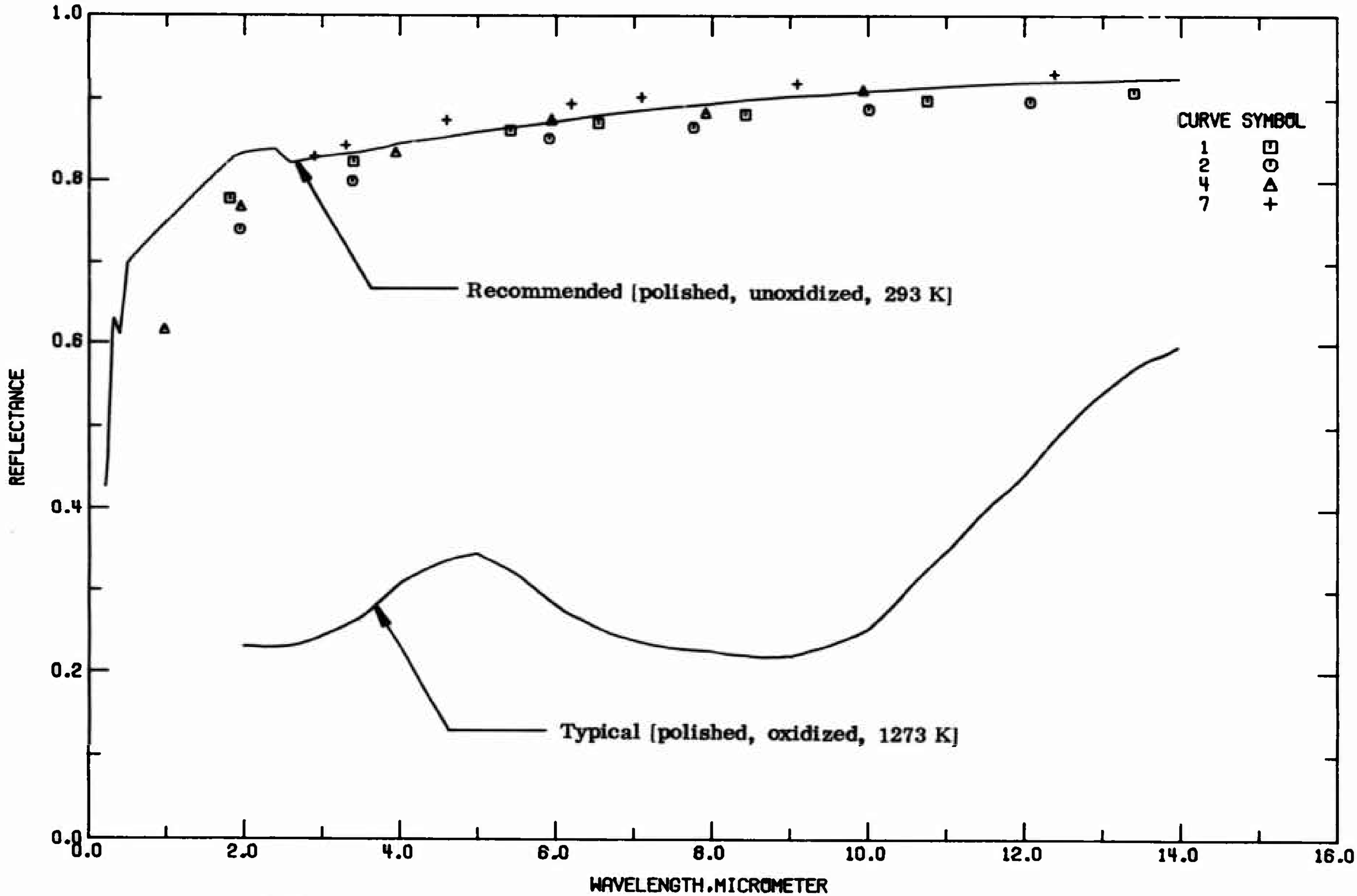


FIGURE 3-4. RECOMMENDED NORMAL SPECTRAL REFLECTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE).

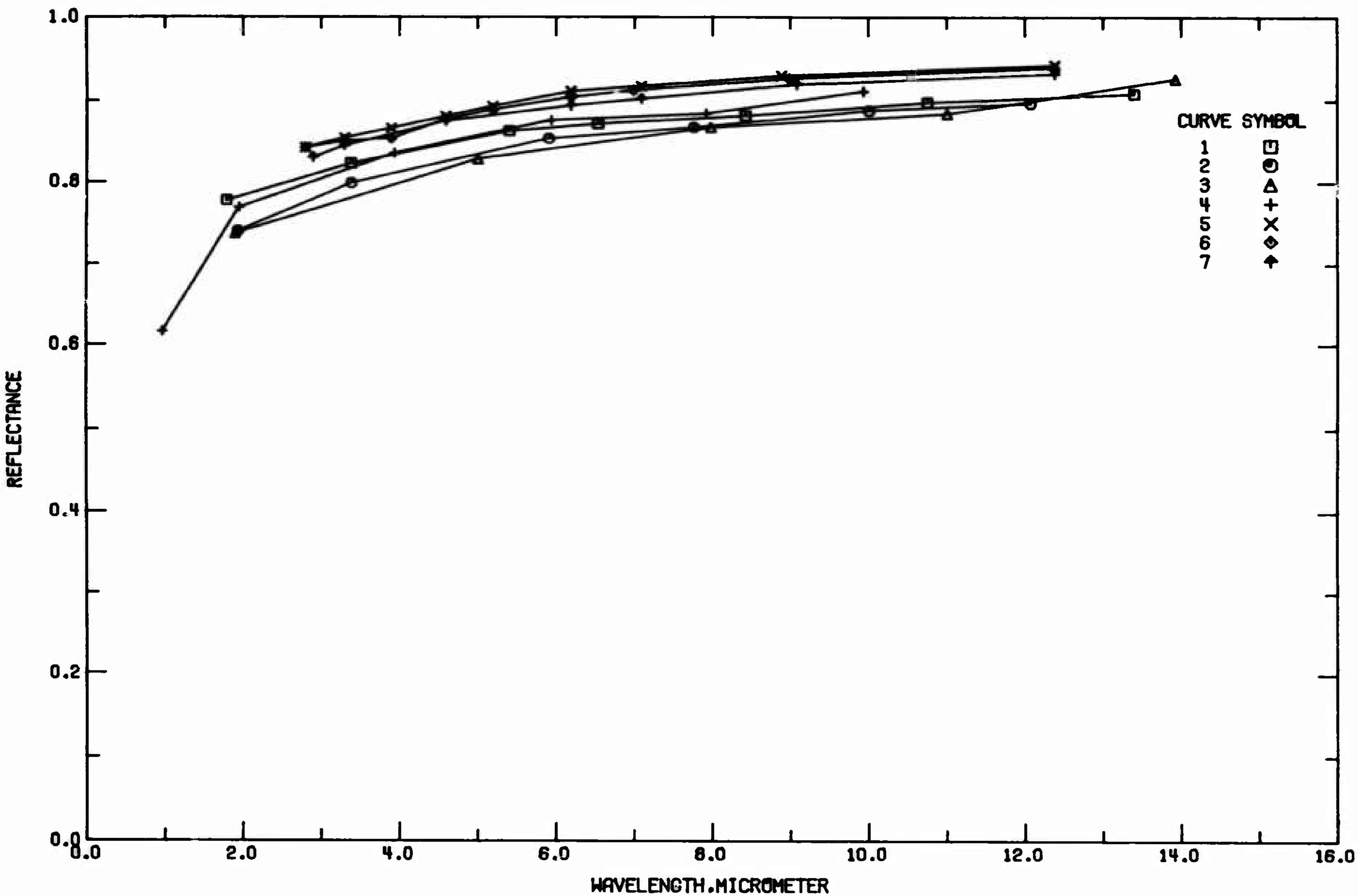


FIGURE 3-5. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF AISI 304 STAINLESS STEEL(WAVELENGTH DEPENDENCE).

TABLE 3-6. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF AISI 304 STAINLESS STEEL (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T33512	Leigh, C.H.	1962	1.81-26.01	298		Nominal composition: 18.00-20.00 Cr, 8.00-12.00 Ni, 2.00 max Mn, 1.00 max Si, 0.08 max C, Fe balance; polished; converted from $R(2\pi\,0^\circ)$; data extracted from smooth curve; $\theta=0^\circ$, $\omega'=2\pi$.
2	T33512	Leigh, C.H.	1962	1.94-26.01	298		Similar to the above specimen and conditions except damaged by particle impact.
3	T33512	Leigh, C.H.	1962	1.90-25.99	77		Similar to the above specimen and conditions.
4	T68866	Stockham, L.W.	1972	0.97-9.95	300		Specimen cut from 1 1/2 in. bar stock, milled to thickness of 1/4 in. and polished using standard techniques; RMS roughness 0.03 ±0.005 μ.
5	T45583	Jones, M.C. and Palmer, D.C.	1969	2.8-295.8	77		Sample ground in form of a flat disk 11/16 in. diameter and about 1/8 in. thick; relative measurement where energy reflected from a sample compared with that from a calibrated reference surface which is chosen to use films derived from very pure gold (799.999 pure) deposited from vapor on highly polished flat glass substrates under high vacuum or ultrahigh-vacuum conditions; commercial spectrophotometer having nominal wavelength range from 1-700 μm.
6	T45583	Jones, M.C. and Palmer, D.C.	1969	2.8-295.8	105		Similar to the above specimen except measured at 105 K.
7	T45583	Jones, M.C. and Palmer, D.C.	1969	2.9-295.9	297		Similar to the above specimen except measured at 297 K.

TABLE 3-7. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 298.	
1.81	0.777
3.40	0.822
5.42	0.862
6.55	0.871
8.44	0.881
10.77	0.897
13.42	0.907
15.90	0.908
18.98	0.919
21.65	0.923
26.01	0.924
CURVE 2	
T = 298.	
1.94	0.739
3.39	0.798
5.92	0.852
7.77	0.866
10.02	0.887
12.09	0.896
14.02	0.898
16.65	0.902
18.70	0.898
20.67	0.890
22.32	0.895
24.41	0.899
26.01	0.899
CURVE 3	
T = 77.	
1.90	0.736
5.01	0.827
7.99	0.866
11.02	0.883
13.95	0.924
15.81	0.903
18.02	0.888

λ	ρ
CURVE 3 (CONT.)	
22.01	0.889
23.98	0.895
25.99	0.899
CURVE 4	
T = 300.	
0.97	0.615
1.95	0.768
3.94	0.834
5.95	0.875
7.93	0.883
9.95	0.910
CURVE 5	
T = 77.	
2.8	0.841
3.3	0.853
3.9	0.865
4.6	0.880
5.2	0.892
6.2	0.910
7.1	0.916
8.9	0.928
12.4	0.940
14.1	0.946
21.7	0.954
25.4	0.949
28.4	0.951
33.1	0.963
39.2	0.962
49.4	0.967
56.1	0.966
65.3	0.963
79.5	0.969

λ	ρ
CURVE 6	
T = 105.	
2.8	0.841
3.3	0.849
3.9	0.852
4.6	0.876
5.2	0.888
6.2	0.903
7.0	0.911
9.0	0.925
12.4	0.937
14.1	0.942
21.7	0.954
25.5	0.954
28.4	0.959
33.1	0.961
56.1	0.966
65.3	0.964
78.5	0.964
CURVE 7	
T = 297.	
2.9	0.829
3.3	0.843
4.6	0.874
6.2	0.893
7.1	0.901
9.1	0.918
12.4	0.930
14.3	0.934
21.8	0.942
25.5	0.949
29.0	0.949
33.1	0.952
39.2	0.955
49.3	0.958
56.1	0.962
65.3	0.959
78.5	0.965

d. Normal Spectral Reflectance (Temperature Dependence)

There is no experimental data available for this property. Two provisional values, tabulated in Table 3-8 and shown in Figure 3-6, were generated for 3.8 μ and 10.6 μ, respectively, covering the temperature range from room temperature to the melting point. The relation $\rho_\lambda + \alpha_\lambda = 1$ was employed for this case. Data for α_λ are available in Section 4.3.g. These values are considered accurate to about $\pm 20\%$ for the entire temperature range.

TABLE 3-8. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF AISI 304 STAINLESS STEEL (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

T	ρ	T	ρ
POLISHED		POLISHED	
λ = 3.8		λ = 10.6	
293.	0.863	293.	0.912
300.	0.862	300.	0.911
400.	0.857	400.	0.907
500.	0.852	500.	0.903
600.	0.846	600.	0.900
700.	0.842	700.	0.897
800.	0.835	800.	0.894
900.	0.83	900.	0.890
1000.	0.824	1000.	0.887
1100.	0.820	1100.	0.883
1200.	0.814	1200.	0.880
1300.	0.808	1300.	0.877
1400.	0.804	1400.	0.873
1500.	0.798	1500.	0.871
1600.	0.793	1600.	0.868
1700.	0.788	1700.	0.864
1727.	0.787	1727.	0.864

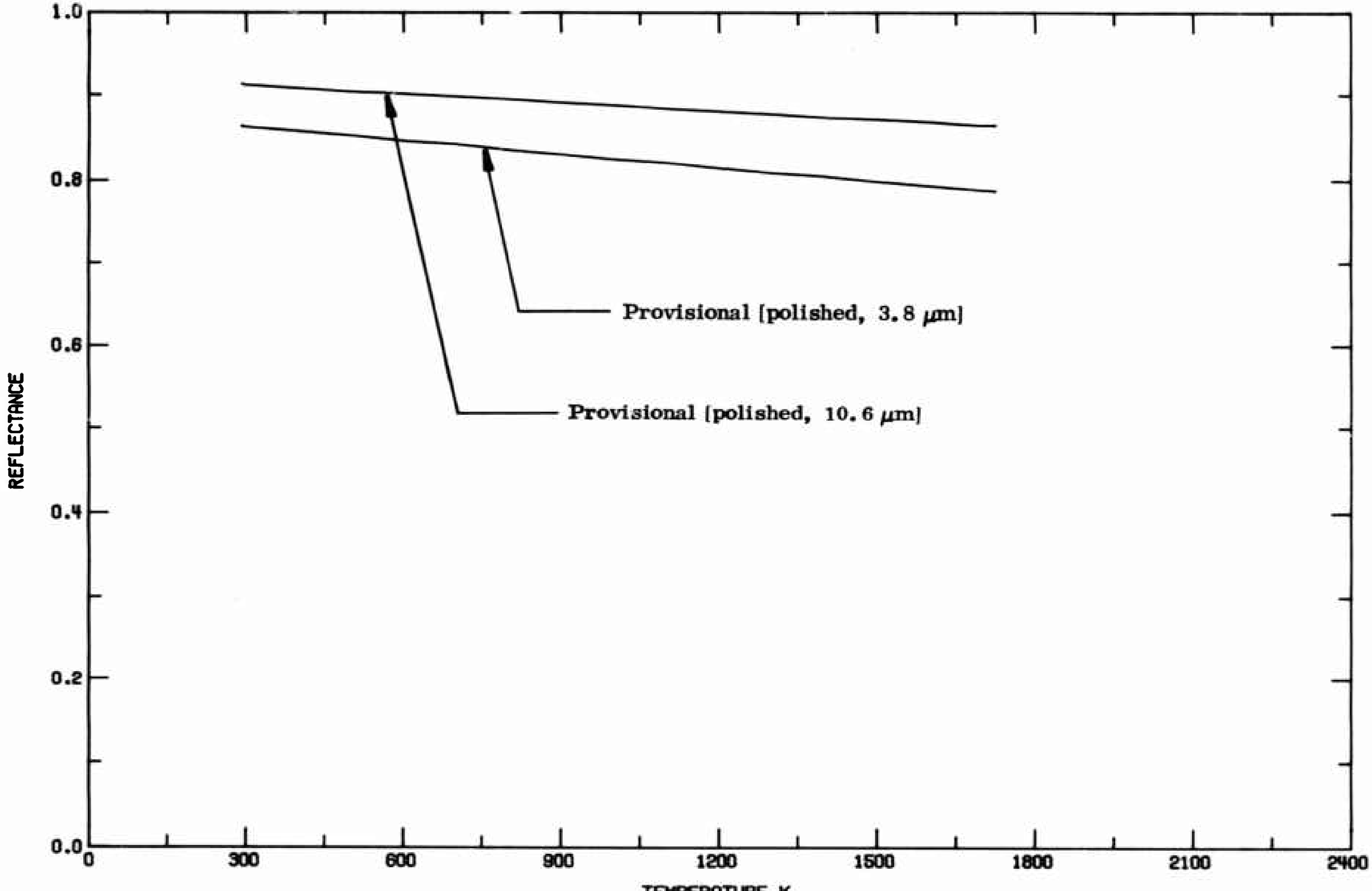


FIGURE 3-6. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF AISI 304 STAINLESS STEEL (TEMPERATURE DEPENDENCE).

e. Angular Spectral Reflectance (Wavelength Dependence)

There are three sets of experimental data available for the wavelength dependence (0.1-0.2 μm) of the angular spectral reflectance of AISI 304 Stainless Steel at temperature 300 K. These are tabulated in Table 3-10 and shown in Figure 3-7.

No recommendations were made because of the lack of information in the wavelength range which we are interested in.

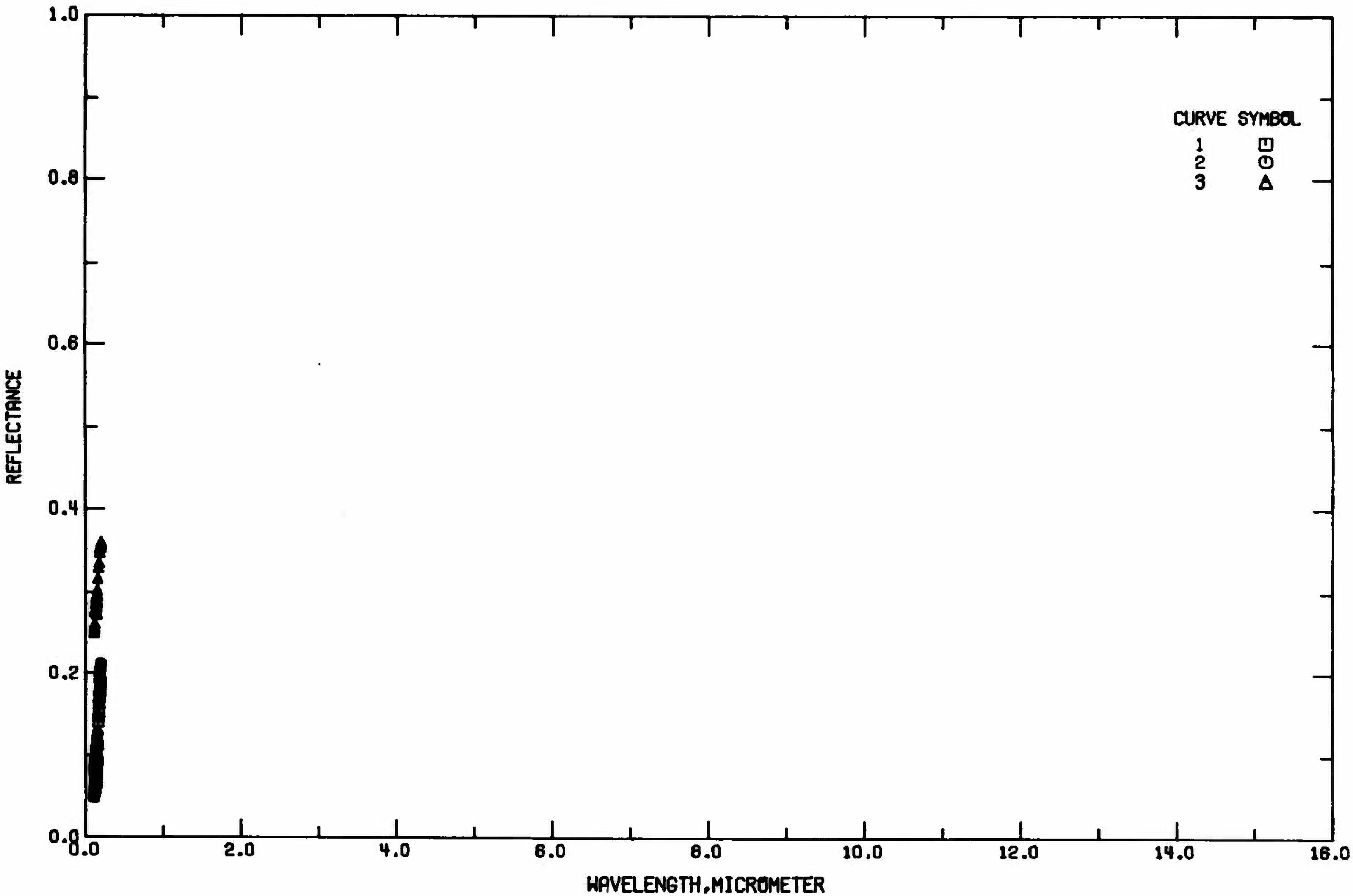


FIGURE 3-7. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF AISI 304 STAINLESS STEEL(WAVELENGTH DEPENDENCE).

TABLE 3-9. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF AISI 304 STAINLESS STEEL (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T77362	Marmo, F. F., Engelman, A., and Schultz, E. D.	1967	0.1-0.2	300		The top and bottom parts of reflectometer contain a rotary push-pull vacuum cell with an indicating pointer and a fixed 360 degree protractor, angle of incidence of 20 degree; θ=20°.
2	T77362	Marmo, F. F., et al.	1967	0.1-0.2	300		Similar to the above specimen except angle of incidence of 45 degree; θ=45°.
3	T77362	Marmo, F. F., et al.	1967	0.1-0.2	300		Similar to the above specimen except angle of incidence of 70 degree; θ=70°.

TABLE 3-10. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 300.	
0.1115	0.050
0.1146	0.053
0.1161	0.056
0.1176	0.058
0.1189	0.060
0.1216	0.062
0.1254	0.066
0.1278	0.072
0.1344	0.076
0.1357	0.076
0.1377	0.076
0.1395	0.074
0.1436	0.069
0.1464	0.067
0.1467	0.069
0.1517	0.078
0.1532	0.085
0.1544	0.090
0.1581	0.093
0.1608	0.112
0.1703	0.140
0.1753	0.152
0.1803	0.163
0.1853	0.171
0.1903	0.178
0.1953	0.184
0.2003	0.188
CURVE 2	
T = 300.	
0.1115	0.079
0.1146	0.082
0.1161	0.085
0.1176	0.086
0.1189	0.089
0.1216	0.091
0.1254	0.093
0.1278	0.098
CURVE 2 (CONT.)	
0.1344	0.107
0.1357	0.109
0.1377	0.108
0.1395	0.103
0.1436	0.096
0.1464	0.095
0.1487	0.099
0.1517	0.108
0.1532	0.115
0.1544	0.121
0.1581	0.126
0.1608	0.146
0.1703	0.164
0.1753	0.175
0.1803	0.190
0.1853	0.197
0.1903	0.205
0.1953	0.208
0.2003	0.212
CURVE 3	
T = 300.	
0.1115	0.250
0.1146	0.251
0.1161	0.255
0.1176	0.258
0.1189	0.262
0.1216	0.276
0.1254	0.279
0.1278	0.286
0.1344	0.290
0.1357	0.294
0.1377	0.289
0.1395	0.262
0.1436	0.274
0.1464	0.274
0.1487	0.273
0.1517	0.286
0.1532	0.295
CURVE 3 (CONT.)	
0.1544	0.302
0.1581	0.295
0.1608	0.316
0.1703	0.330
0.1753	0.336
0.1803	0.349
0.1853	0.354
0.1903	0.356
0.1953	0.358
0.2003	0.361

f. Normal Spectral Absorptance (Wavelength Dependence)

There are five sets of experimental data available for the wavelength dependence (2.8-20 μm) of the normal spectral absorptance of AISI 304 Stainless Steel near room temperature. These values are tabulated in Table 3-13 and shown in Figure 3-9.

The recommended values for polished surfaces at 293 K, tabulated in Table 3-11 and shown in Figure 3-8 are primarily based on the work by Harmon [A00003] and the recommended data for normal spectral emittance of wavelength dependence (see Section 4.3.a).

The accuracy for this recommended data is considered to within ±15% for the entire wavelength range.

The typical values at 1273 K, tabulated in Table 3-11 and shown in Figure 3-8, are for polished and oxidized surfaces. These values were calculated by using the Kirchhoff law, $\alpha_\lambda = \epsilon_\lambda$, where the values for the normal spectral emittance are shown in Table 3-1. These values are considered accurate to about ±30% over the entire wavelength range.

TABLE 3-11. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α
POLISHED		POLISHED		POLISHED OXIDIZED	
T = 293		T = 293 (CONT.)		T = 1273	
0.22	0.572	13.50	0.077	2.00	0.768B†
0.25	0.532	14.00	0.076	2.50	0.769B
0.30	0.392			2.80	0.762B
0.32	0.372			3.00	0.754B
0.40	0.392			3.50	0.729B
0.50	0.302			3.80	0.708B
0.80	0.272			4.00	0.690B
1.00	0.252			4.50	0.664B
1.50	0.206			5.00	0.650B
1.88	0.172			5.50	0.680B
2.00	0.167			6.00	0.717B
2.20	0.164			6.50	0.744B
2.40	0.162			7.00	0.760B
2.50	0.172			7.50	0.770B
2.60	0.180			8.00	0.776B
2.80	0.176			8.50	0.780B
3.00	0.172			9.00	0.781B
3.50	0.166			9.50	0.765B
3.80	0.160			10.00	0.746B
4.00	0.156			10.60	0.689B
4.50	0.148			11.00	0.648B
5.00	0.140			11.50	0.600B
5.50	0.134			12.00	0.554B
6.00	0.128			12.50	0.502B
6.50	0.121			13.00	0.456B
7.00	0.116			13.50	0.424B
7.50	0.111			14.00	0.402B
8.00	0.107				
8.50	0.102				
9.00	0.098				
9.50	0.096				
10.00	0.092				
10.50	0.089				
10.60	0.088				
11.00	0.086				
11.50	0.083				
12.00	0.081				
12.50	0.080				
13.00	0.079				

† VALUE FOLLOWED BY A "B" IS TYPICAL.

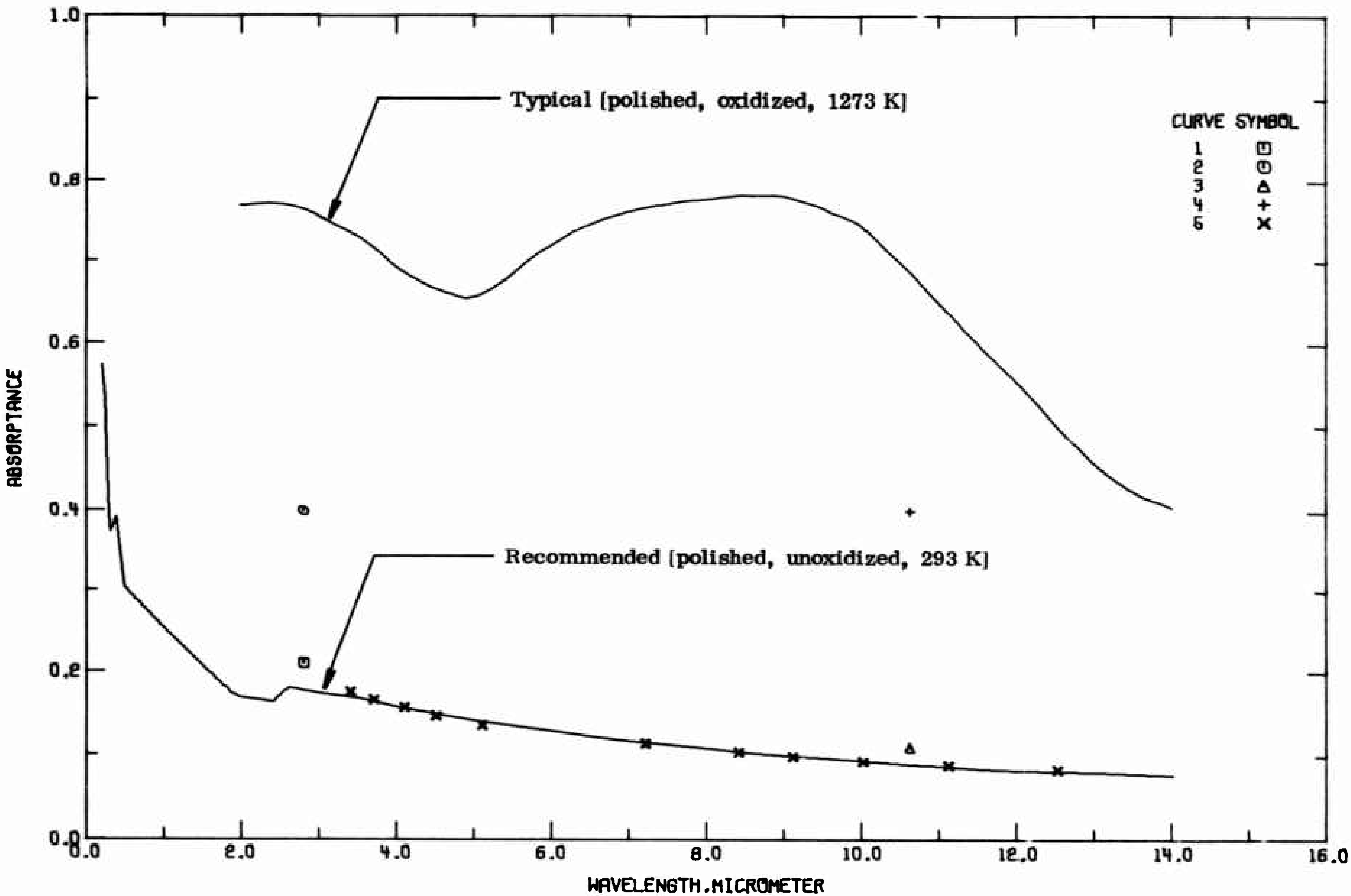


FIGURE 3-8. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE).

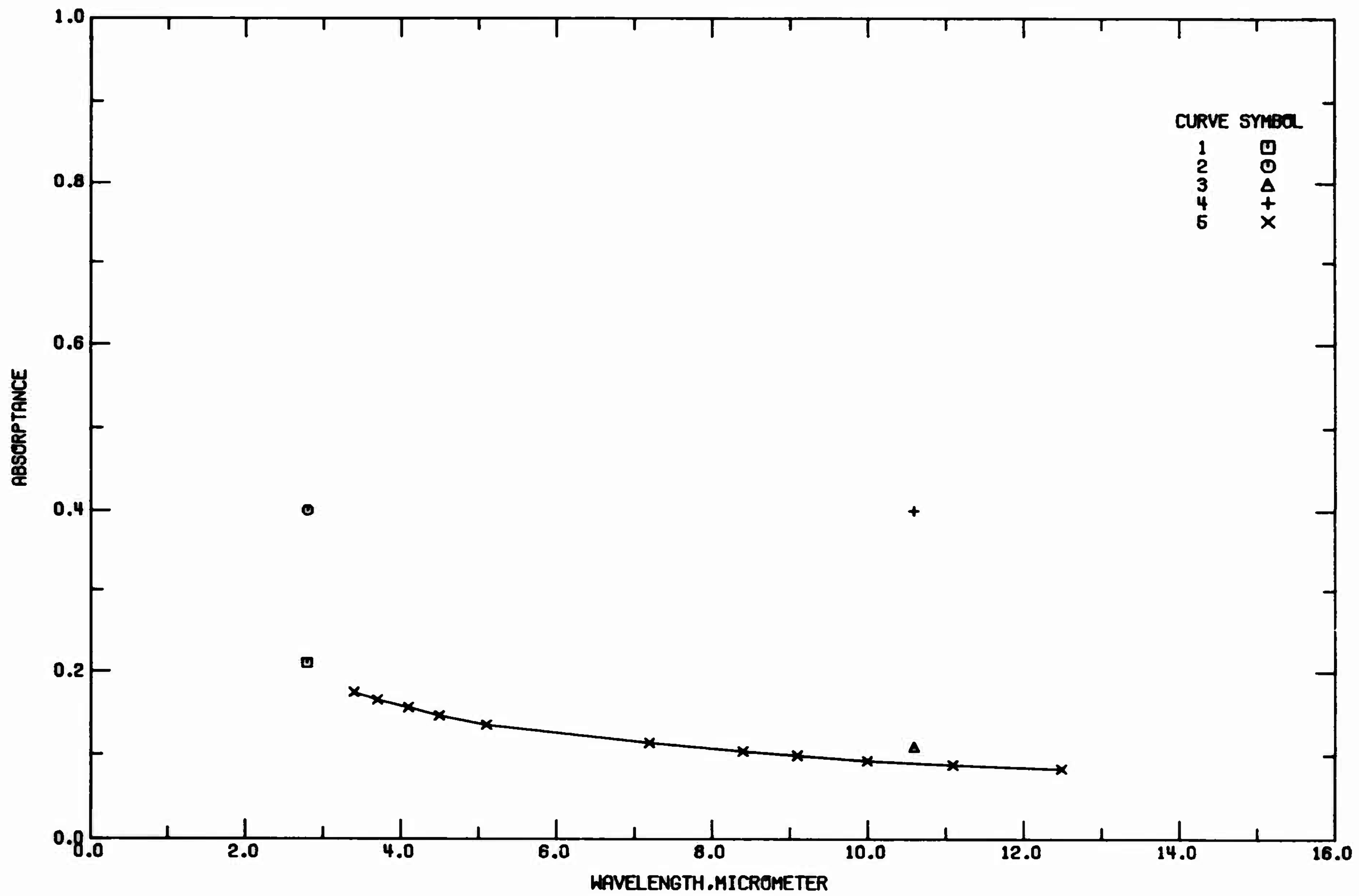


FIGURE 3-9. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF AISI 304 STAINLESS STEEL(WAVELENGTH DEPENDENCE).

TABLE 3-12. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF AISI 304 STAINLESS STEEL (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00016	Neighbours, J.R., (Editor)	1974	2.8	300		Polished surface condition.
2	A00016	Neighbours, J.R., (Editor)	1974	2.8	300		As received surface condition.
3	A00016	Neighbours, J.R., (Editor)	1974	10.6	300		Polished surface condition.
4	A00016	Neighbours, J.R., (Editor)	1974	10.6	300		As received surface condition.
5	A00003	Harmon, N.F., (Editor)	1974	3.42-20.00	293		High quality surface.

TABLE 3-13. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF AISI 304 STAINLESS STEEL (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α
CURVE 1 T = 300.	
2.8	0.21
CURVE 2 T = 300.	
2.8	0.4
CURVE 3 T = 300.	
10.6	0.11
CURVE 4 T = 300.	
10.6	0.4
CURVE 5 T = 293.	
3.4	0.175
3.7	0.166
4.1	0.157
4.5	0.147
5.1	0.136
7.2	0.114
8.4	0.104
9.1	0.099
10.0	0.093
11.1	0.088
12.5	0.083
14.3	0.076
16.6	0.071
19.1	0.064
20.0	0.061

g. Normal Spectral Absorptance (Temperature Dependence)

There are eight sets of data available for the temperature dependence (293-1727 K) of the normal spectral absorptance of AISI 304 Stainless Steel covering the wavelength range from 2.8 μm to 10.6 μm. These values are tabulated in Table 3-16 and shown in Figure 3-11.

The provisional values for the polished surface for 3.8 μm and 10.6 μm are tabulated in Table 3-14 and shown in Figure 3-10 covering the temperature range from 293 to 1727 K.

The provisional values for 3.8 μm are primarily based on the work by Neighbours [A00016] who theoretically calculated the normal spectral absorptance from the equation $\alpha_\lambda = A_0 + A_2 T$ assuming that this AISI 304 Stainless Steel obeyed the Drude-Lorentz theory.

The provisional values at 10.6 μm were generated from the calculations of Neighbours [A00016] and Cunningham and Laughlin [E66194] who used the Hagen-Rubens relation, and the experimental values of Harmon [A00003]. The accuracy of both provisional curves is about ±20% over the entire temperature range.

TABLE 3-14. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF AISI 304 STAINLESS STEEL (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

T	α	T	α
POLSIHED		POLISHED	
λ = 3.8		λ = 10.6	
293.	0.137	293.	0.088
300.	0.138	300.	0.089
400.	0.143	400.	0.093
500.	0.148	500.	0.097
600.	0.154	600.	0.100
700.	0.158	700.	0.103
800.	0.165	800.	0.106
900.	0.170	900.	0.110
1000.	0.176	1000.	0.113
1100.	0.180	1100.	0.117
1200.	0.186	1200.	0.120
1300.	0.192	1300.	0.123
1400.	0.196	1400.	0.127
1500.	0.202	1500.	0.129
1600.	0.207	1600.	0.132
1700.	0.212	1700.	0.136
1727.	0.213	1727.	0.136

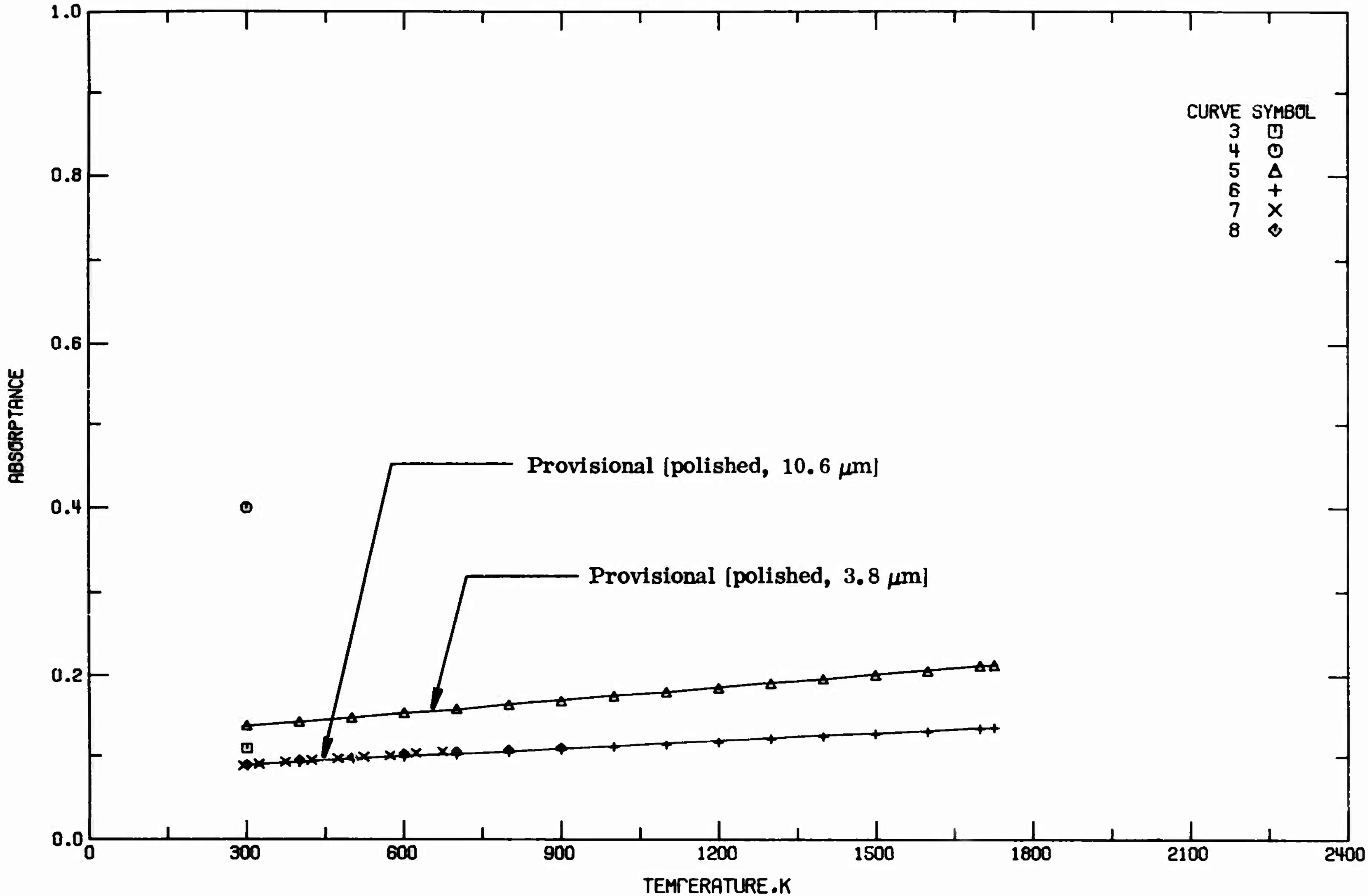


FIGURE 3-10. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF AISI 304 STAINLESS STEEL(TEMPERATURE DEPENDENCE).

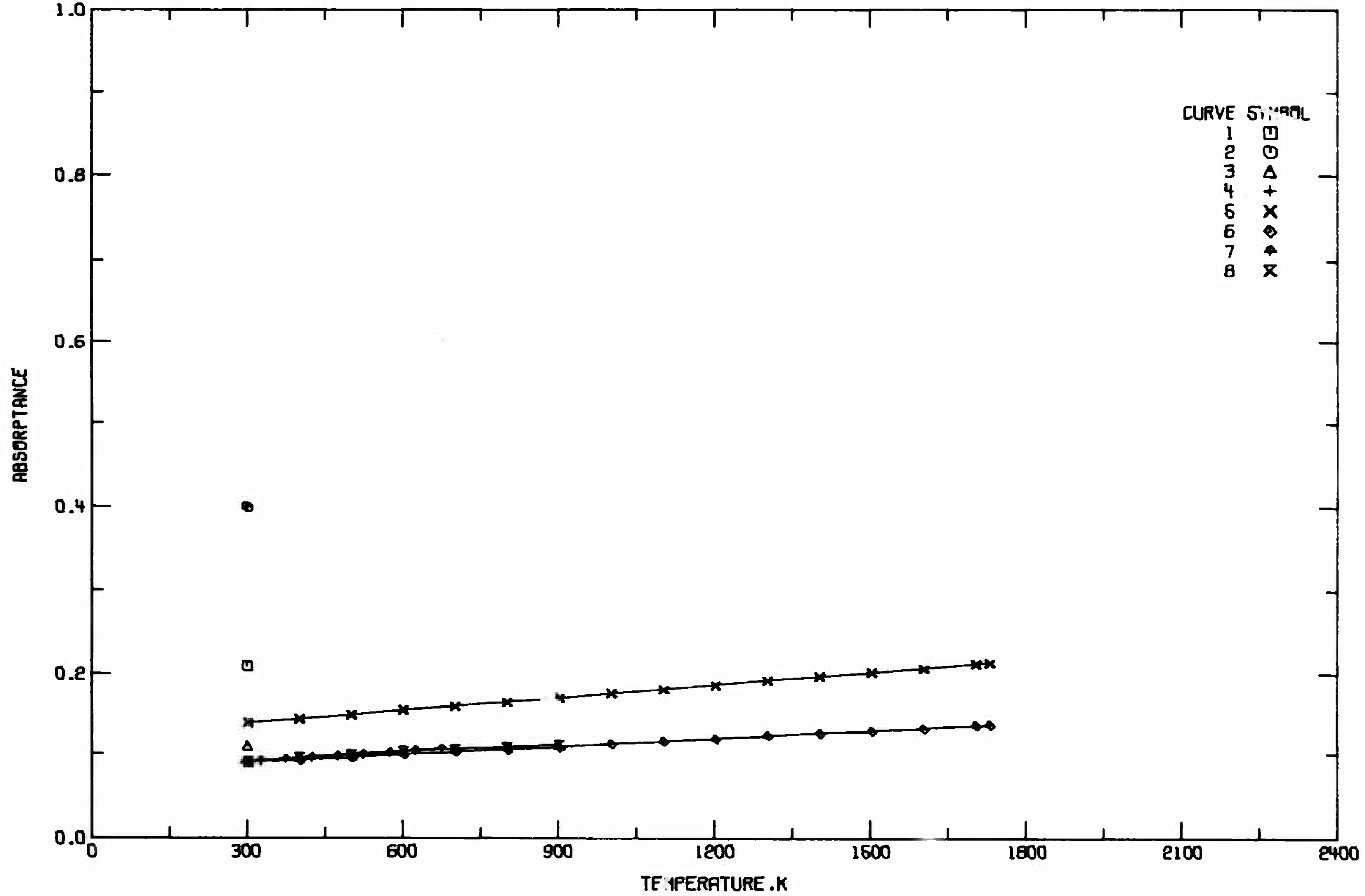


FIGURE 3-11. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF AISI 304 STAINLESS STEEL(TEMPERATURE DEPENDENCE).

TABLE 3-15. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF AISI 304 STAINLESS STEEL (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00016	Neighbours, J.R., (Editor)	1974	2.8	300		Polished surface condition.
2	A00016	Neighbours, J.R., (Editor)	1974	2.8	300		As received surface condition.
3	A00016	Neighbours, J.R., (Editor)	1974	10.6	300		Polished surface condition.
4	A00016	Neighbours, J.R., (Editor)	1974	10.6	300		As received surface condition.
5	A00016	Neighbours, J.R., (Editor)	1974	3.8	300-1727		Theoretical calculation of absorptance from 300 K to the melting point (1727 K) from the equation $A = A_0 + A_1T$, based on the assumption that the alloys obey the Drude-Lorentz theory, where $A_0 = 0.122$ and $A_1 = 5.27 \times 10^{-5}\ K^{-1}$
6	A00016	Neighbours, J.R., (Editor)	1974	10.6	300-1727		The above specimen except $A_0 = 7.91 \times 10^{-2}$ and $A_1 = 3.27 \times 10^{-5}\ K^{-1}$.
7	A00003	Harmon, N.F., (Editor)	1974	10.6	293-773		Averaged values of two runs.
8	E66194	Cunningham, S.S. and Laughlin, W.T.	1974	10.6	300-900		Calculated value of absorptance, which is obtained by evaluating the Hagen-Rubens relation.

TABLE 3-16. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF AISI 304 STAINLESS STEEL (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

T	α	T	α	T	α
CURVE 1 λ = 2.8		CURVE 6 λ = 10.6		CURVE 8 (CONT.)	
300.	0.21	300.	0.089	900.	0.111
		400.	0.092		
CURVE 2 λ = 2.8		500.	0.095		
		600.	0.099		
		700.	0.102		
300.	0.4	800.	0.105		
		900.	0.108		
CURVE 3 λ = 10.6		1000.	0.112		
		1100.	0.115		
		1200.	0.118		
300.	0.11	1300.	0.122		
		1400.	0.125		
CURVE 4 λ = 10.6		1500.	0.128		
		1600.	0.131		
		1700.	0.135		
300.	0.4	1727.	0.136		
CURVE 5 λ = 3.8		CURVE 7 λ = 10.6			
300.	0.138	293.	0.088		
400.	0.143	323.	0.090		
500.	0.148	373.	0.093		
600.	0.154	423.	0.095		
700.	0.159	473.	0.097		
800.	0.164	523.	0.099		
900.	0.169	573.	0.101		
1000.	0.175	623.	0.104		
1100.	0.180	673.	0.106		
1200.	0.185				
1300.	0.191	CURVE 8 λ = 10.6			
1400.	0.196				
1500.	0.201				
1600.	0.206	300.	0.089		
1700.	0.212	400.	0.095		
1727.	0.213	500.	0.099		
		600.	0.103		
		700.	0.106		
		800.	0.108		

h. Transmittance

Although it is true that metals and alloys in the form of extremely thin films may be transparent for a wide wavelength range, they are opaque if the thickness is greater than several hundred angstroms.

As an aircraft/spacecraft structural material, this alloy is not used in the form of extremely thin films and therefore is opaque; that is, its transmittance is zero.

4.4. Titanium Alloy Ti-6Al-4V

Titanium alloy Ti-6Al-4V was first introduced in 1954 [A00008]. Its nominal composition is 6% Al, 4% V, and balance Ti. The melting range of this alloy is 1803 to 1908 K. Its density is 4.424 g cm^{-3}, which is 56% of that of steel. It can be heat-treated to ultimate strength in excess of 170,000 psi and has excellent fatigue properties and crack propagation characteristics.

This alloy has an alpha lean beta composition. Addition of the six percent aluminum stabilizes the alpha phase resulting in an increase in $\alpha + \beta \rightarrow \beta$ transformation temperature from 1156 to 1266 K. It also increases the elevated temperature strength level. Addition of four percent vanadium increases the strength level by two mechanisms: firstly by substitutional solid solution hardening and secondly, by stabilizing the beta or high temperature phase, thereby making β to α hardening reaction possible through heat treatment. The addition of Vanadium improves hot workability by causing more of the ductile β-phase to be present at hot working temperatures.

Descaling of the alloy can be accomplished mechanically by methods such as grinding and grit blasting; and chemically by acid pickling or by immersion in molten caustic or hydride bath.

Pickling of the alloy is generally done either for dimensional reasons or for removing surface (oxygen) contamination. This is done in bath containing HNO_3 and HF with ratios of 10:1. HNO_3 acts as an inhibitor to prevent the titanium from picking up the free hydrogen from the Ti-HF reaction.

This alloy has the following different designations:

Republic Steel Co., Titanium Metal Division: Ti-6Al-4V
Special Metal Division: RS-120A

Crucible Steel Co., Titanium Division: C-120AV

Harvey Aluminum Co., Titanium Division: HA-6510

Reactive Metal Products: MST-6Al-4V

Aeronautical Material Specifications: 4928A

Military designation: OS-10737

a. Normal Spectral Emittance (Wavelength Dependence)

There are four sets of experimental data available for the wavelength dependence (0.3-15 μm) of the normal spectral emittance of Titanium Alloy Ti-6Al-4V for oxidized and anodized surfaces. These are tabulated in Table 4-3 and shown in Figure 4-2.

(1) 0.032 μm Finish Alloy

There are no experimental data available for this alloy; however, the recommended values are tabulated in Table 4-1 and shown in Figure 4-1 for Titanium Alloy Ti-6Al-4V alloy of nominal composition and 0.032 μm finish. These values were calculated from the normal spectral reflectance data for the similar material (see Section 4.5.d).

(2) Oxidized Titanium Alloy Ti-6Al-4V

The recommended values tabulated in Table 4-1 and shown in Figure 4-1 for oxidized material are primarily from the investigation of Gravina and Katz [T22613]. These values are considered accurate to within ±15% over the entire wavelength range. The values calculated from the normal spectral reflectance data of Grimm and Fannin [A00001] for a specimen after heating for 15 minutes in air are in good agreement with the recommended values.

(3) Anodized Titanium Alloy Ti-6Al-4V

The recommended values tabulated in Table 4-1 and shown in Figure 4-1 for chromic acid anodized surface are primarily from the investigation of Cunnington and Funai [T22613]. These values are considered accurate to within 15% over the entire wavelength range. It is very important to note that since different anodizing processes may produce entirely different surface finishes, which in turn will affect the radiative properties. This makes it impossible to give recommended values for general cases. Therefore, the above recommended values are for chromic acid anodized surface only. (See Section 4.1.c for further explanation.)

TABLE 4-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε
0.032 μm FINISH ALLOY T = 293		0.032 μm FINISH ANODIZED T = 700		OXIDIZED HEATED IN AIR T = 700	
0.4	0.657	2.8	0.798	2.8	0.778
0.5	0.639	3.0	0.785	3.0	0.764
1.0	0.577	3.5	0.758	3.5	0.733
1.5	0.535	3.8	0.747	3.8	0.714
2.0	0.503	4.0	0.744	4.0	0.700
2.5	0.474	4.5	0.740	4.5	0.672
2.8	0.460	5.0	0.738	5.0	0.646
3.0	0.450	5.5	0.735	5.5	0.624
3.5	0.429	6.0	0.734	6.0	0.607
3.8	0.418	6.3	0.730	6.5	0.595
4.0	0.411	6.5	0.726	7.0	0.584
4.5	0.396	6.6	0.720	7.5	0.580
5.0	0.384	6.8	0.691	8.0	0.575
5.5	0.374	7.0	0.646	8.5	0.574
6.0	0.365	7.2	0.616	9.0	0.572
6.5	0.358	7.4	0.604	9.5	0.571
7.0	0.351	7.5	0.603	10.0	0.570
7.5	0.346	7.6	0.607	10.5	0.570
8.0	0.340	7.8	0.646	10.6	0.570
8.5	0.335	8.0	0.746		
9.0	0.330	8.2	0.868		
9.5	0.326	8.4	0.915		
10.0	0.322	8.5	0.928		
10.5	0.318	8.7	0.938		
10.6	0.317	9.0	0.934		
11.0	0.314	9.5	0.923		
11.5	0.308	10.0	0.920		
12.0	0.304	10.5	0.924		
12.5	0.300	11.0	0.929		
13.0	0.295	11.5	0.935		
13.5	0.292	12.0	0.939		
14.0	0.288	12.5	0.940		
14.5	0.284	13.0	0.933		
15.0	0.280	13.5	0.919		
		14.0	0.903		
		14.5	0.894		
		15.0	0.864		

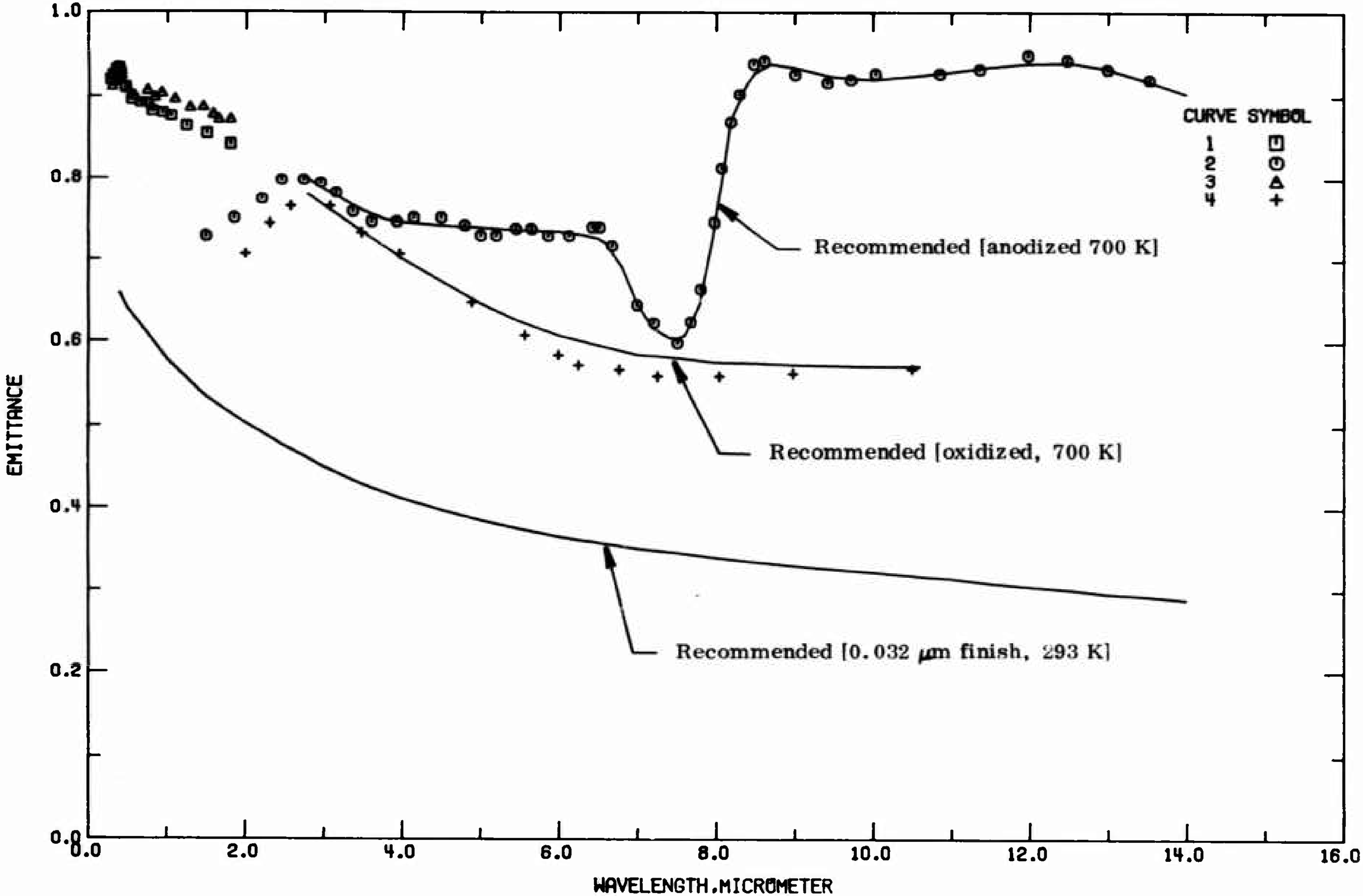


FIGURE 4-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE).

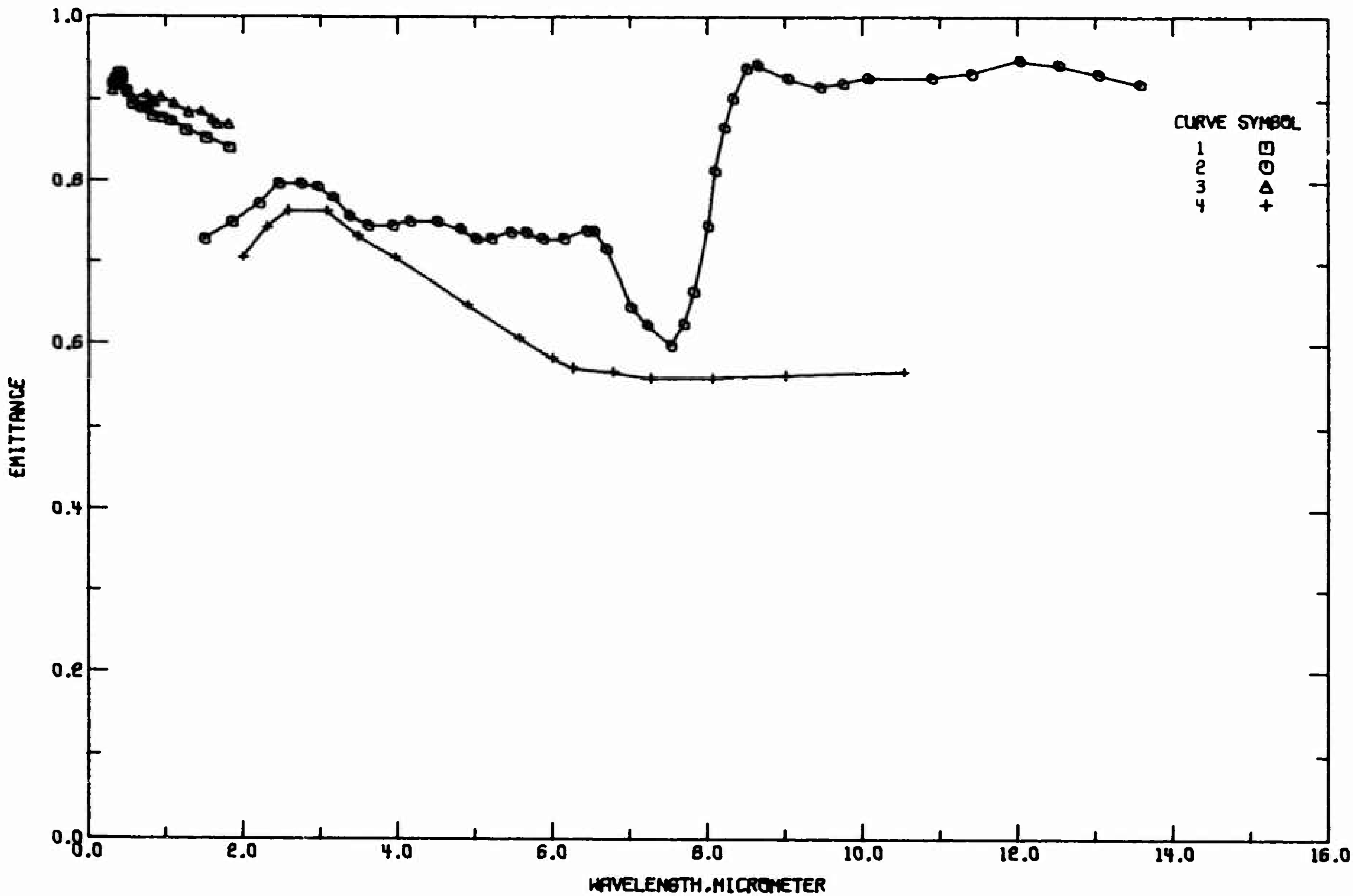


FIGURE 4-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE).

TABLE 4-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF TITANIUM ALLOY Ti-6Al-4V (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T68303	Cunnington, G.R. and Funai, A.J.	1972	0.29-1.81	298		MSFC anodized Ti-6Al-4V; measurements before high temperature measurements.
2	T68308	Cunnington, G.R. and Funai, A.J.	1972	1.5-15	700		The above specimen.
3	T68308	Cunnington, G.R. and Funai, A.J.	1972	0.3-1.81	298		The above specimen; measurements after high temperature measurements.
4	T22613	Gravina, A. and Katz, M.	1961	2-10.5	700		Oxidized specimen.

TABLE 4-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 1	
T = 293.	
0.29	0.919
0.32	0.924
0.36	0.930
0.39	0.932
0.41	0.926
0.47	0.910
0.55	0.894
0.66	0.890
0.73	0.890
0.81	0.879
0.94	0.877
1.05	0.873
1.25	0.861
1.51	0.852
1.81	0.840
CURVE 2	
T = 700.	
1.50	0.728
1.86	0.749
2.21	0.772
2.46	0.797
2.74	0.797
2.96	0.793
3.16	0.780
3.37	0.757
3.61	0.745
3.93	0.745
4.15	0.750
4.50	0.750
4.80	0.741
5.00	0.729
5.20	0.729
5.45	0.737
5.65	0.737
5.86	0.729
6.13	0.729
6.43	0.739

λ	ε
CURVE 2 (CONT.)	
6.52	0.739
6.68	0.717
7.00	0.644
7.21	0.623
7.51	0.598
7.68	0.624
7.81	0.663
7.99	0.745
8.08	0.813
8.20	0.866
8.31	0.902
8.49	0.938
8.63	0.942
9.02	0.926
9.43	0.916
9.73	0.920
10.05	0.927
10.87	0.927
11.38	0.932
12.00	0.948
12.50	0.943
13.01	0.932
13.55	0.920
14.18	0.909
14.60	0.887
15.00	0.860
CURVE 3	
T = 293.	
0.30	0.912
0.34	0.918
0.37	0.922
0.41	0.922
0.50	0.909
0.58	0.900
0.75	0.907
0.80	0.886
0.84	0.898
0.93	0.904

λ	ε
CURVE 3 (CONT.)	
1.10	0.896
1.29	0.885
1.46	0.886
1.59	0.876
1.66	0.870
1.81	0.870
CURVE 4	
T = 700.	
2.00	0.706
2.31	0.743
2.58	0.763
3.08	0.763
3.48	0.732
3.96	0.706
4.89	0.647
5.56	0.607
5.99	0.583
6.25	0.571
6.77	0.566
7.26	0.559
8.05	0.559
8.99	0.562
10.51	0.567

b. Normal Spectral Emittance (Temperature Dependence)

There are 22 experimental data sets for the temperature dependence (1100-1700 K) at $\lambda = 0.65$ μm of the normal spectral emittance of Titanium Alloy Ti-6Al-4V. These are tabulated in Table 4-5 and shown in Figure 4-3. Since no measurements are located at higher wavelengths, no recommendations are made.

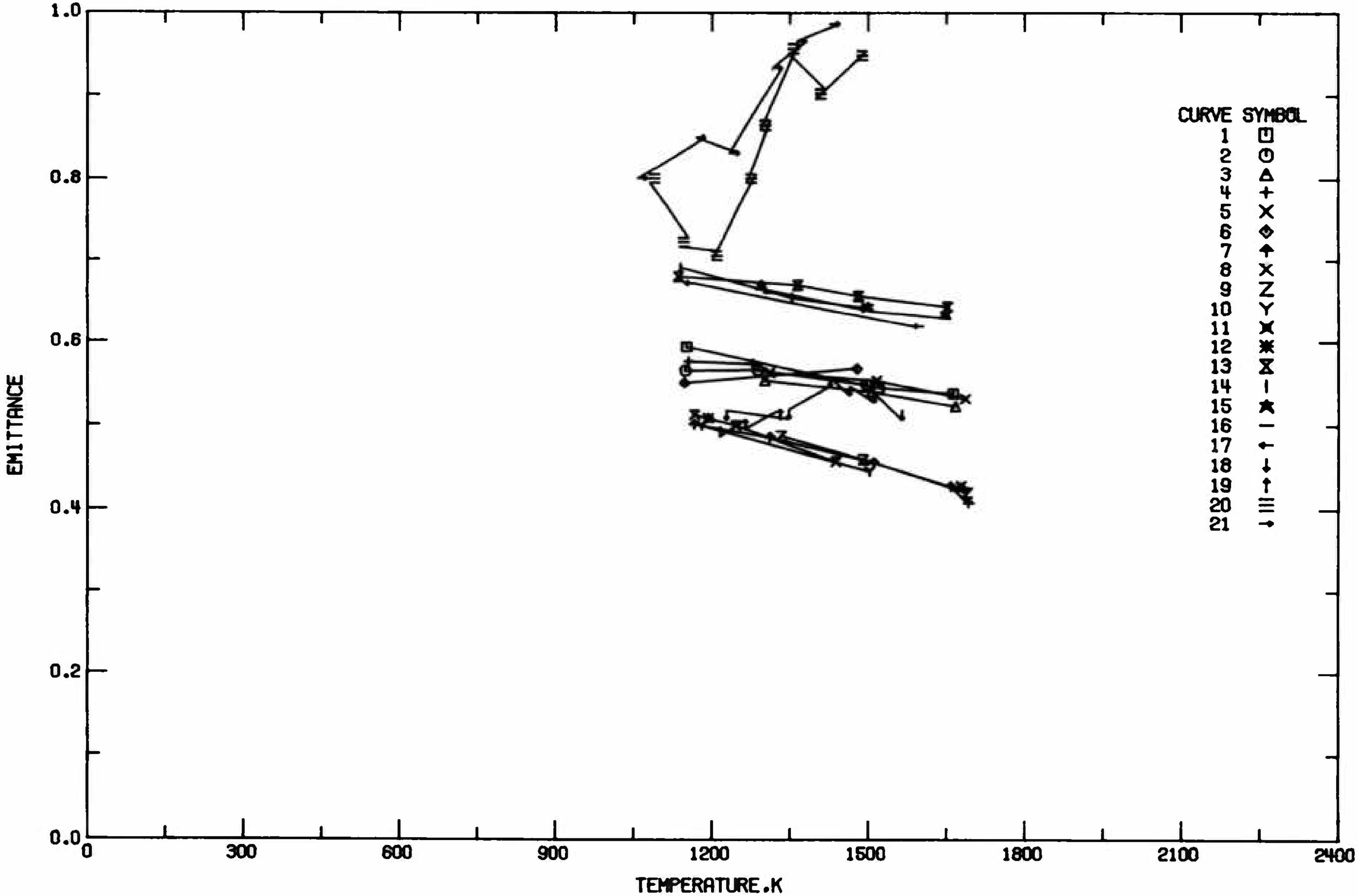


FIGURE 4-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF TITANIUM ALLOY TI-6AL-4V (TEMPERATURE DEPENDENCE).

TABLE 4-4. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF TITANIUM ALLOY Ti-6Al-4V (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T6979	Betz, H.T., Olson, O.H., Schurin, B.D., and Morris, J.C.	1957	0.665	1152-1665		Nominal composition, specimen as received, cleaned with liquid detergent, measurements in vacuum (5×10^{-4} mm Hg) with increasing temperature, cycle one; $\theta' \sim 0°$.
2	T6979	Betz, H.T., et al.	1957	0.665	1150-1498		Similar to the above specimen and condition, decreasing temperature, cycle one.
3	T6979	Betz, H.T., et al.	1957	0.665	1303-1669		Similar to the above specimen and condition, increasing temperature, cycle two.
4	T6979	Betz, H.T., et al.	1957	0.665	1156-1280		Similar to the above specimen and condition, decreasing temperature, cycle two.
5	T6979	Betz, H.T., et al.	1957	0.665	1312-1688		Similar to the above specimen and condition, increasing temperature, cycle three.
6	T6979	Betz, H.T., et al.	1957	0.665	1148-1480		Similar to the above specimen and condition, decreasing temperature, cycle three.
7	T6979	Betz, H.T., et al.	1957	0.665	1166-1693		Similar to the above specimen; polished with fine polishing compounds on a buffing wheel, increasing temperature cycle one.
8	T6979	Betz, H.T., et al.	1957	0.665	1439-1167		Similar to the above specimen and condition, decreasing temperature, cycle one.
9	T6979	Betz, H.T., et al.	1957	0.665	1334-1691		Similar to the above specimen and condition, increasing temperature, cycle two.
10	T6979	Betz, H.T., et al.	1957	0.665	1504-1181		Similar to the above specimen and condition, decreasing temperature, cycle two.
11	T6979	Betz, H.T., et al.	1957	0.665	1679		Similar to the above specimen and condition, cycle three.
12	T6979	Betz, H.T., et al.	1957	0.665	1194		Similar to the above specimen and condition, cycle three.
13	T6979	Betz, H.T., et al.	1957	0.665	1136-1654		Similar to the specimen from curve 1 except oxidized in air at red heat for 30 min, increasing temperature, cycle 1.
14	T6979	Betz, H.T., et al.	1957	0.665	1491-1140		Similar to the above specimen and condition, decreasing temperature, cycle one.
15	T6979	Betz, H.T., et al.	1957	0.665	1649-1296		Similar to the above specimen and condition, decreasing temperature, cycle one.
16	T6979	Betz, H.T., et al.	1957	0.665	1312		Similar to the above specimen and condition, cycle two.
17	T6979	Betz, H.T., et al.	1957	0.665	1597-1159		Similar to the above specimen and condition, cycle two.
18	T6979	Betz, H.T., et al.	1957	0.665	1566-1229		Similar to the above specimen and condition, cycle three.
19	T23145	Sklarew, S. and Rebensteine, A.S.	1963	0.65	1556-1229		Titanium alloy 6Al-4l; 5.5-6.5Al, 3.5-4.5V, 0.1 max C, 0.3 max Fe, 0.05 max N_2, 0.0125 max H_2, 0.15 max O_2, Ti balance; polished; surface roughness 2 to 3 μRMS; measurements in vacuum (3 to 4×10^{-4} mm Hg); measurements with decreasing temperature.
20	T23145	Sklarew, S. and Rebensteine, A.S.	1963	0.65	1216-1332		Similar to the above specimen and condition, measurements with increasing temperature.
21*	T23145	Sklarew, S. and Rebensteine, A.S.	1963	0.65	1490-1090		Similar to the above specimen except coated with Rokide "C", decreasing temperature.
22*	T23145	Sklarew, S. and Rebensteine, A.S.	1963	0.65	1066-1438		Similar to the above specimen except measurements with increasing temperature.

* Not shown in figure.

TABLE 4-5. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF TITANIUM ALLOY TI-6AL-4V (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ
CURVE 1	
λ = 0.665	
1152.	0.592
1521.	0.544
1665.	0.537
CURVE 2	
λ = 0.665	
1150.	0.564
1290.	0.565
1498.	0.548
CURVE 3	
λ = 0.665	
1303.	0.553
1508.	0.539
1669.	0.522
CURVE 4	
λ = 0.665	
1156.	0.575
1280.	0.572
CURVE 5	
λ = 0.665	
1312.	0.562
1518.	0.553
1688.	0.531
CURVE 6	
λ = 0.665	
1148.	0.550
1480.	0.567
CURVE 7	
λ = 0.665	
1166.	0.500
1312.	0.485
1512.	0.455
1659.	0.427
1693.	0.407
CURVE 8	
λ = 0.665	
1167.	0.512
1247.	0.499
1439.	0.456
CURVE 9	
λ = 0.665	
1334.	0.487
1492.	0.459
1691.	0.420
CURVE 10	
λ = 0.665	
1181.	0.499
1584.	0.445
CURVE 11	
λ = 0.665	
1679.	0.428
CURVE 12	
λ = 0.665	
1194.	0.508
CURVE 13	
λ = 0.665	
1136.	0.679
1366.	0.669
1483.	0.656
1654.	0.643
CURVE 14	
λ = 0.665	
1140.	0.690
1355.	0.654
1491.	0.642
CURVE 15	
λ = 0.665	
1296.	0.669
1501.	0.643
1649.	0.634
CURVE 16	
λ = 0.665	
1312.	0.660
CURVE 17	
λ = 0.665	
159.	0.671
1597.	0.619
CURVE 18	
λ = 0.65	
1229.	0.512
1349.	0.513
1429.	0.552
1466.	0.541
1513.	0.533
1566.	0.512
CURVE 19	
λ = 0.65	
1216.	0.491
1265.	0.501
1332.	0.513
CURVE 20	
λ = 0.65	
1090.	0.800
1147.	0.722
1210.	0.705
1276.	0.800
1304.	0.864
1358.	0.955
1410.	0.901
1490.	0.947
CURVE 21	
λ = 0.65	
1066.	0.800
1179.	0.850
1244.	0.832
1327.	0.932
1374.	0.964
1438.	0.985

c. Angular Spectral Emittance (Wavelength Dependence)

There are no experimental data located in the literature. The recommended values at 293 K tabulated in Table 4-6 and shown in Figure 4-4 are for pickled Titanium Ti-6Al-4V alloy of thickness 40 mil and the incident angle, $\theta = 45°$. These values calculated from the angular spectral reflectance data tabulated in Table 4-12 are considered accurate to within ±15% at reported wavelengths. Unfortunately the authors gave only four data points, so no attempt was made to interpolate their data.

TABLE 4-6. RECOMMENDED ANGULAR SPECTRAL EMITTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

λ	ϵ
PICKLED ALLOY T = 293	
2.8	0.42
3.8	0.37
5.0	0.31
10.6	0.22

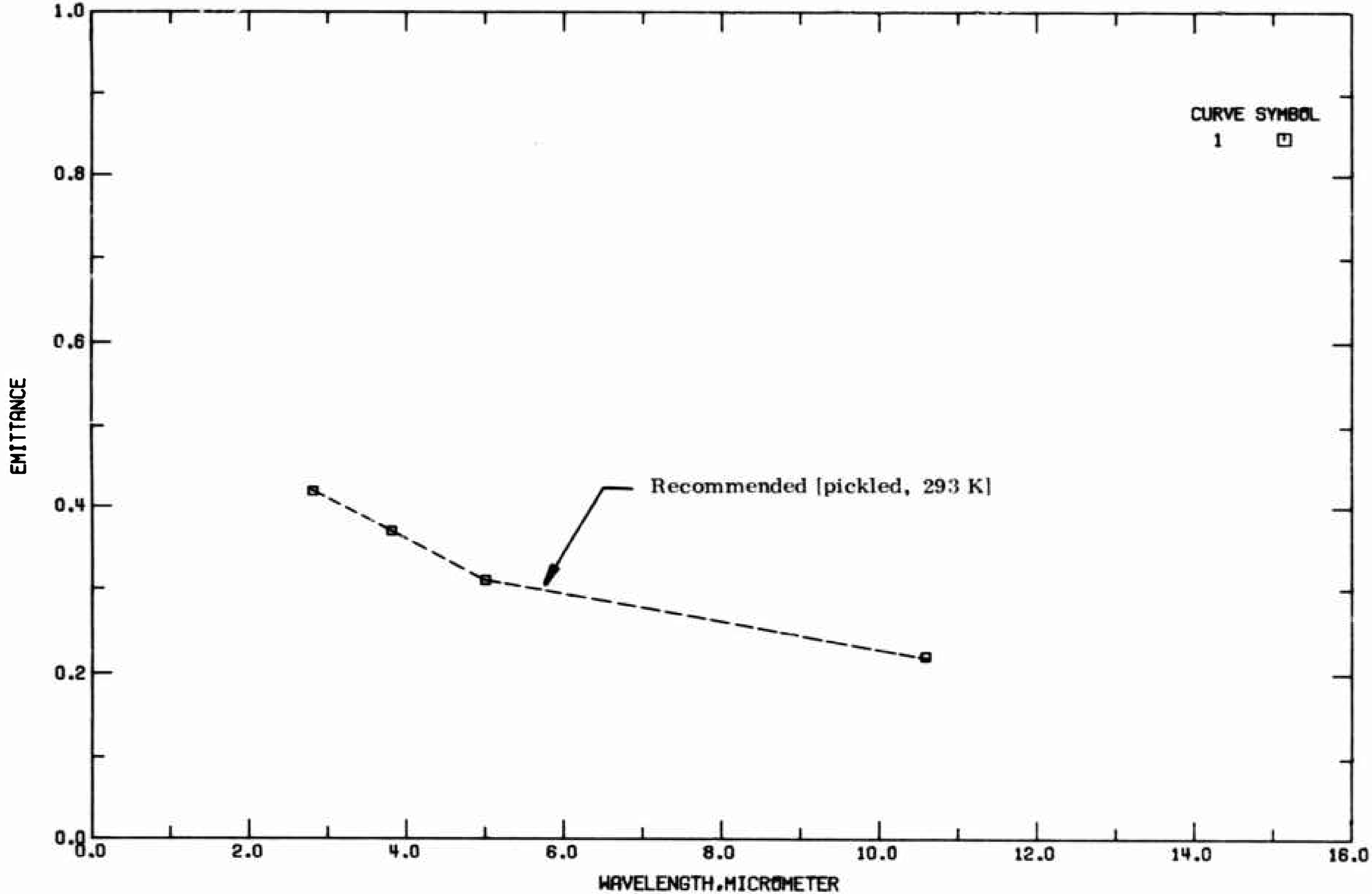


FIGURE 4-4. RECOMMENDED ANGULAR SPECTRAL EMITTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE).

d. Normal Spectral Reflectance (Wavelength Dependence)

There are 13 experimental data sets available for the wavelength dependence (2.8-10.6 μm) of the normal spectral reflectance of Titanium Alloy Ti-6Al-4V. These are tabulated in Table 4-9 and shown in Figure 4-6.

(1) 0.032 μm Finish Alloy

The recommended values at 293 K tabulated in Table 4-7 and shown in Figure 4-5 for Titanium Alloy Ti-6Al-4V with 0.032 μm finish are primarily from the investigations of Shipley and Thostesen [T40746]. These values are considered accurate to within ±15% over the entire wavelength range.

(2) Oxidized Titanium Alloy Ti-6Al-4V

The recommended values tabulated in Table 4-7 and shown in Figure 4-5 for oxidized Titanium Alloy Ti-6Al-4V are primarily from the investigation of Grimm and Fannin [A00001] and are for the material which has been heated in air for 15 minutes. These are considered accurate to within ±15% over the entire wavelength range. The values calculated from the normal emittance data of Gravina and Katz [T22613] for similar oxidized Titanium Alloy Ti-6Al-4V are in good agreement with the recommended values.

(3) Anodized Titanium Alloy Ti-6Al-4V

The recommended values tabulated in Table 4-7 and shown in Figure 4-5 for chromic acid anodized surface were calculated from the normal spectral emittance data of Cunnington and Funai [T22613]. These are considered accurate to about ±15% over the entire wavelength range. (See Section 4.1.c and 4.5.a for further details.)

TABLE 4-7. RECOMMENDED NORMAL SPECTRAL REFLECTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ
0.032 μm FINISH ALLOY T = 293		0.032 μm FINISH ANODIZED T = 700		OXIDIZED HEATED IN AIR T = 700	
0.4	0.343	2.8	0.202	2.8	0.222
0.5	0.361	3.0	0.215	3.0	0.236
1.0	0.423	3.5	0.242	3.5	0.267
1.5	0.465	3.8	0.253	3.8	0.286
2.0	0.497	4.0	0.256	4.0	0.300
2.5	0.526	4.5	0.260	4.5	0.328
2.8	0.540	5.0	0.262	5.0	0.354
3.0	0.553	5.5	0.265	5.5	0.376
3.5	0.571	6.0	0.266	6.0	0.397
3.8	0.582	6.3	0.270	6.5	0.405
4.0	0.589	6.5	0.274	7.0	0.416
4.5	0.604	6.6	0.280	7.5	0.420
5.0	0.616	6.8	0.309	8.0	0.425
5.5	0.626	7.0	0.354	8.5	0.426
6.0	0.635	7.2	0.384	9.0	0.428
6.5	0.642	7.4	0.396	9.5	0.429
7.0	0.649	7.5	0.397	10.0	0.430
7.5	0.654	7.6	0.393	10.5	0.430
8.0	0.660	7.8	0.354	10.6	0.430
8.5	0.665	8.0	0.254		
9.0	0.670	8.2	0.132		
9.5	0.674	8.4	0.085		
10.0	0.678	8.5	0.072		
10.5	0.682	8.7	0.062		
10.6	0.683	9.0	0.066		
11.0	0.686	9.5	0.077		
11.5	0.692	10.0	0.080		
12.0	0.696	10.5	0.076		
12.5	0.700	11.0	0.071		
13.0	0.705	11.5	0.065		
13.5	0.708	12.0	0.061		
14.0	0.712	12.5	0.060		
14.5	0.716	13.0	0.067		
15.0	0.720	13.5	0.081		
		14.0	0.097		
		14.5	0.106		
		15.0	0.136		

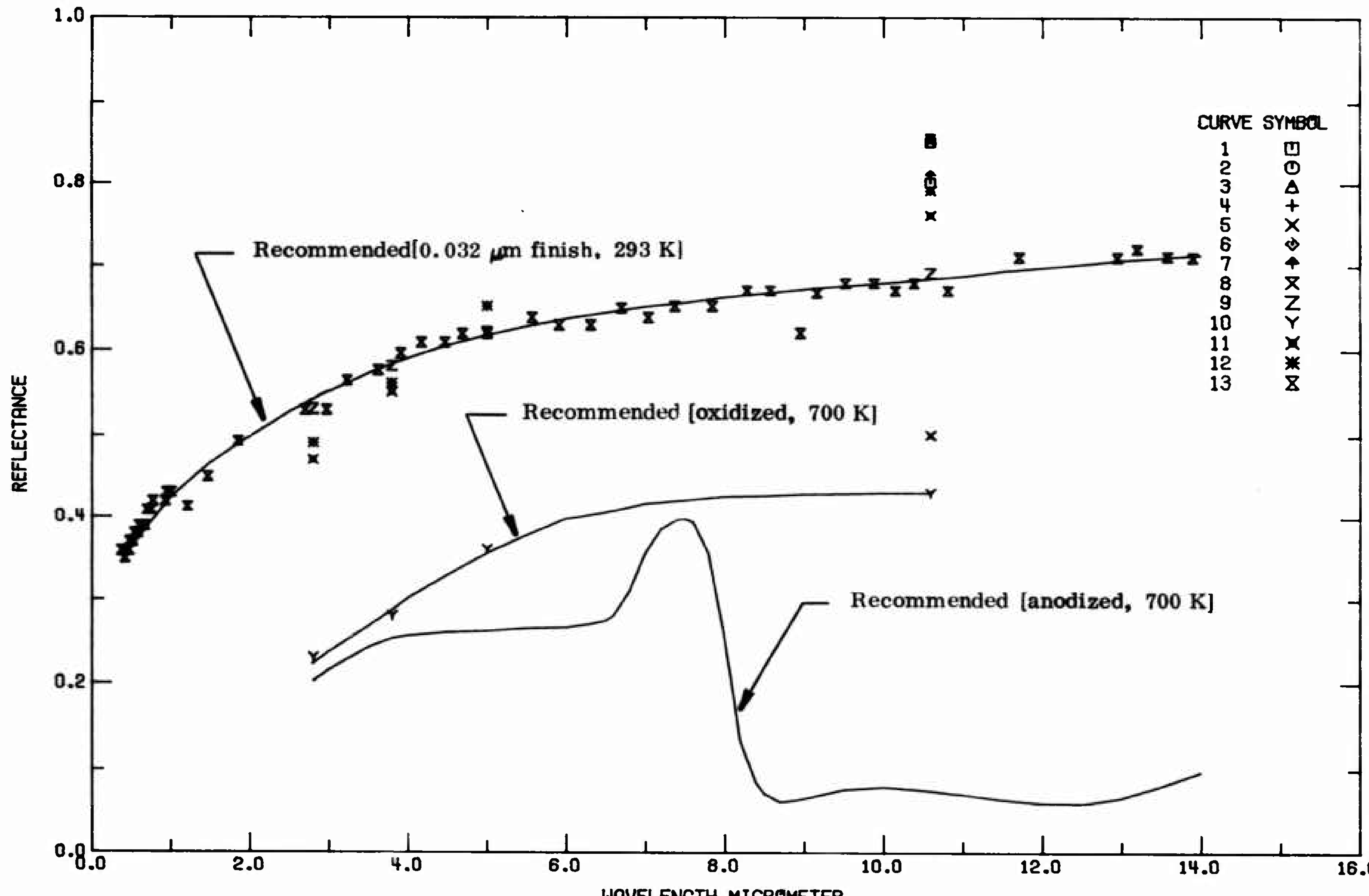


FIGURE 4-5. RECOMMENDED NORMAL SPECTRAL REFLECTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE).

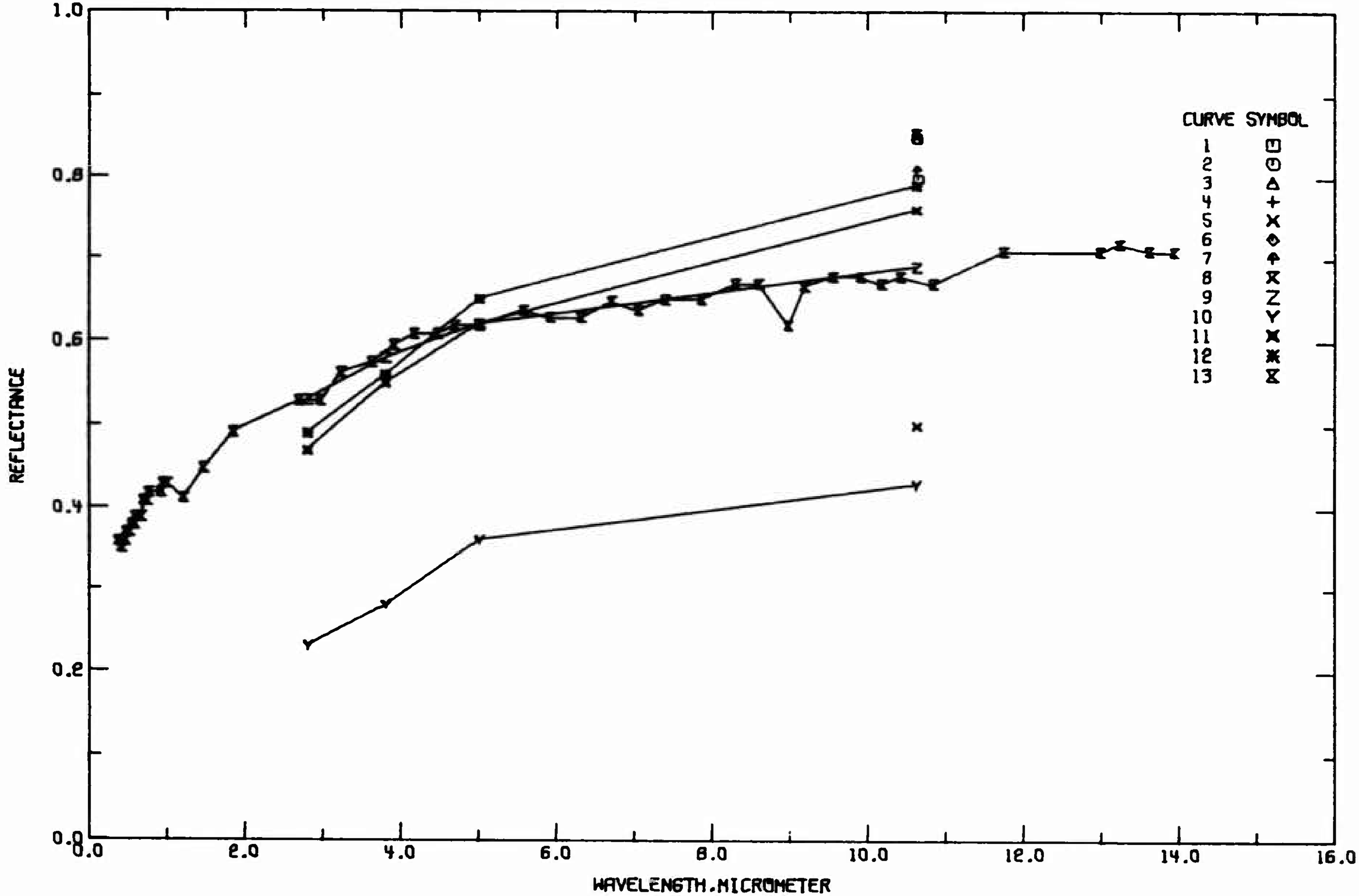


FIGURE 4-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE).

TABLE 4-8. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF TITANIUM ALLOY Ti-6Al-4V (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Specimen from the Rodney Metals, 4 mil.
2	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen except mechanically polished.
3	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Specimen from the Rodney metals, 10 mil.
4	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen except mechanically polished.
5	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the specimen from curve 3 except sand blasted.
6	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the specimen from curve 3 except chemically milled.
7	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Specimen from the Timet Corp.; 15 mil.
8	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen except mechanically polished.
9	A00001	Grimm, T.C. and Fannin, E.R.	1972	2.8-10.6	293		Compilation, 125 μin. finish.
10	A00001	Grimm, T.C. and Fannin, E.R.	1972	2.8-10.6	700		Measurements after being heated in air for 15 min.
11	A00001	Grimm, T.C. and Fannin, E.R.	1972	2.8-10.6	293		Pickled Ti-6Al-4V; thickness: 40 mil; $\theta = 15°$.
12	A00001	Grimm, T.C. and Fannin, E.R.	1972	2.8-10.6	293		Similar to the above specimen except heat treated in air at 644 K for one hr.
13	T40746	Shipley, W.S. and Thostesen, T.O.	1960	0.38-25	300		Nominal composition; "125" finish.

TABLE 4-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 293.	
10.6	0.800
CURVE 2	
T = 293.	
10.6	0.850
CURVE 3	
T = 293.	
10.6	0.850
CURVE 4	
T = 293.	
10.6	0.855
CURVE 5	
T = 293.	
10.6	0.500
CURVE 6	
T = 293.	
10.6	0.855
CURVE 7	
T = 293.	
10.6	0.81
CURVE 8	
T = 293.	
10.6	0.855
CURVE 9	
T = 293.	
2.8	0.53
3.8	0.58
5.0	0.62
10.6	0.69
CURVE 10	
T = 700.	
2.8	0.23
3.8	0.28
5.0	0.36
10.6	0.43
CURVE 11	
T = 293.	
2.8	0.47
3.8	0.55
5.0	0.62
10.6	0.76
CURVE 12	
T = 293.	
2.8	0.49
3.8	0.56
5.0	0.65
10.6	0.79
CURVE 13	
T = 300.	
0.38	0.358
0.40	0.357
0.42	0.349
0.45	0.358
0.47	0.358
0.48	0.369
0.52	0.369
CURVE 13(CONT.)	
0.54	0.379
0.58	0.379
0.60	0.388
0.67	0.388
0.70	0.408
0.75	0.408
0.77	0.419
0.93	0.419
0.95	0.430
1.00	0.430
1.21	0.412
1.47	0.449
1.85	0.492
2.70	0.529
2.97	0.529
3.23	0.563
3.63	0.575
3.91	0.595
4.17	0.608
4.47	0.608
4.69	0.618
5.00	0.618
5.57	0.637
5.91	0.628
6.31	0.628
6.70	0.648
7.04	0.637
7.38	0.650
7.85	0.650
8.29	0.669
8.58	0.669
8.96	0.619
9.17	0.666
9.53	0.678
9.89	0.678
10.16	0.669
10.40	0.678
10.82	0.669
11.72	0.709
12.96	0.709
CURVE 13(CONT.)	
13.21	0.719
13.59	0.710
13.91	0.709
14.26	0.728
14.64	0.700
14.88	0.729
15.16	0.741
15.54	0.729
15.83	0.730
16.13	0.740
17.96	0.740
18.24	0.760
18.93	0.760
19.20	0.750
19.59	0.760
20.00	0.760
20.24	0.770
20.39	0.761
20.68	0.761
20.86	0.772
21.42	0.772
21.61	0.762
21.91	0.780
22.07	0.770
22.25	0.770
22.41	0.780
22.57	0.771
22.72	0.780
22.89	0.78[illegible]
23.08	0.771
23.24	0.771
23.36	0.782
23.54	0.771
23.68	0.779
23.87	0.771
24.31	0.771
24.48	0.760
25.00	0.760

e. Normal Spectral Reflectance (Temperature Dependence)

There are 10 sets of experimental data available for the temperature dependence of the normal spectral reflectance of Titanium Alloy Ti-6Al-4V under various surface conditions. These are tabulated in Table 4-11 and shown in Figure 4-7. In the absence of sufficient data, no recommendations were made.

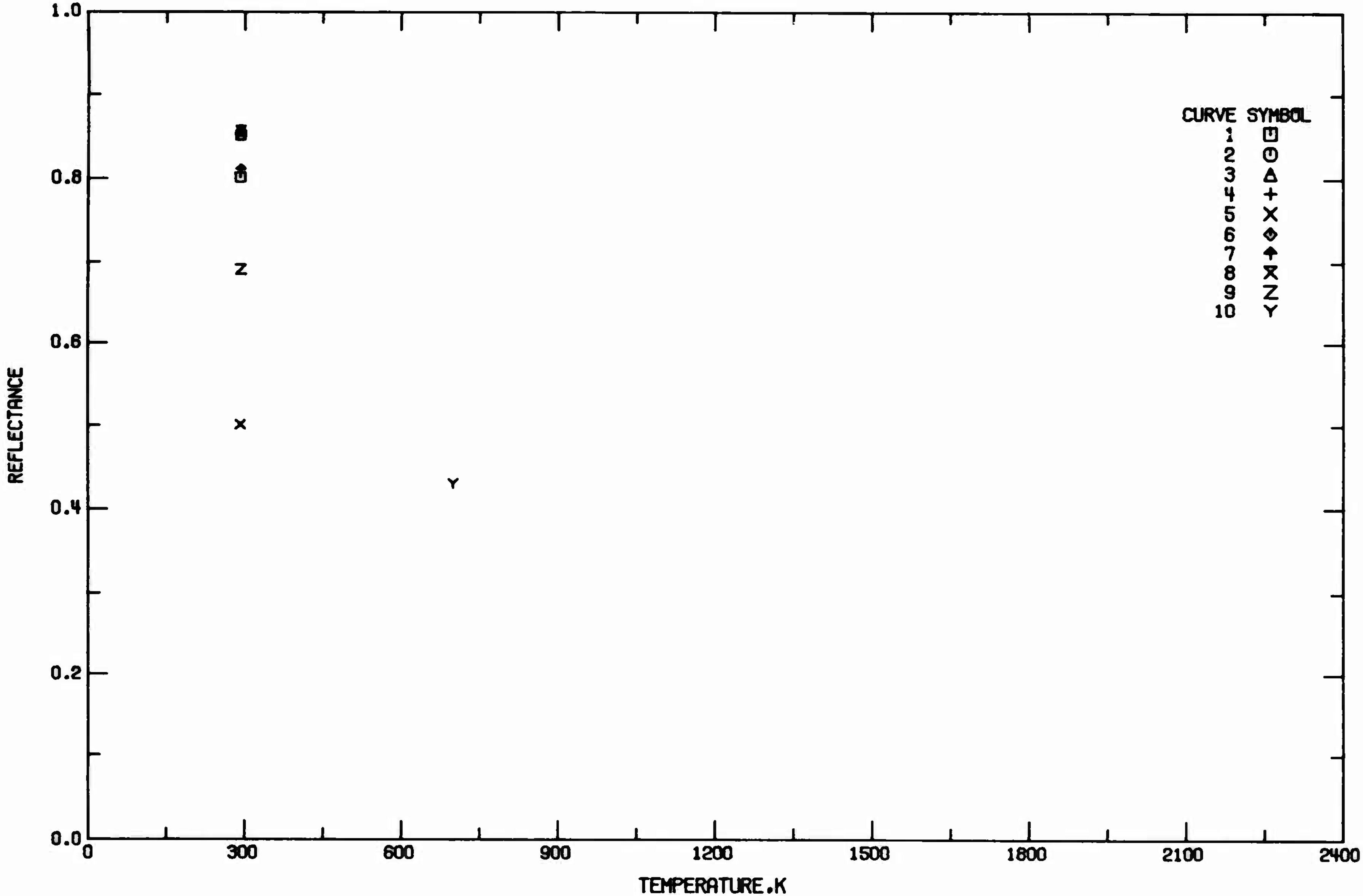


FIGURE 4-7. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF TITANIUM ALLOY TI-6AL-4V (TEMPERATURE DEPENDENCE).

TABLE 4-10. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF TITANIUM ALLOY Ti-6Al-4V (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Specimen from the Rodney Metals, 4 mil.
2	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen except mechanically polished.
3	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Specimen from the Rodney metal, 10 mil.
4	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen except mechanically polished.
5	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the specimen from curve 3 except sand blasted.
6	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the specimen from curve 3 except chemically milled.
7	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Specimen from the Timet Corp.; 15 mil.
8	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen except mechanically polished.
9	A00001	Grimm, T.C. and Fannin, E.R.	1973	10.6	293		Compilation, 125 μ inch finish.
10	A00001	Grimm, T.C. and Fannin, E.R.	1973	10.6	700		Similar to the above specimen, measurements after being heated in air for 15 min.

TABLE 4-11. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF TITANIUM ALLOY TI-6AL-4V (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

T	ρ	T	ρ
CURVE 1 λ = 10.6		CURVE 9 λ = 10.6	
293.	0.800	293.	0.69
CURVE 2 λ = 10.6		CURVE 10 λ = 10.6	
293.	0.850	780.	0.43
CURVE 3 λ = 10.6			
293.	0.850		
CURVE 4 λ = 10.6			
293.	0.855		
CURVE 5 λ = 10.6			
293.	0.500		
CURVE 6 λ = 10.6			
293.	0.855		
CURVE 7 λ = 10.6			
293.	0.810		
CURVE 8 λ = 10.6			
293.	0.855		

f. Angular Spectral Reflectance (Wavelength Dependence)

There is only one set of experimental data that is available. This one is tabulated in Table 4-14 and shown in Figure 4-9.

The recommended values tabulated in Table 4-12 and shown in Figure 4-8 are for 40 mil thick pickled Titanium Alloy Ti-6Al-4V with the incident angle, $\theta = 45^\circ$. These values primarily from the investigation of Grimm and Fannin [A00001] are considered accurate to within ±15% at the reported wavelengths.

TABLE 4-12. RECOMMENDED ANGULAR SPECTRAL REFLECTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ
PICKLED ALLOY T = 293	
2.8	0.58
3.8	0.63
5.0	0.69
10.6	0.78

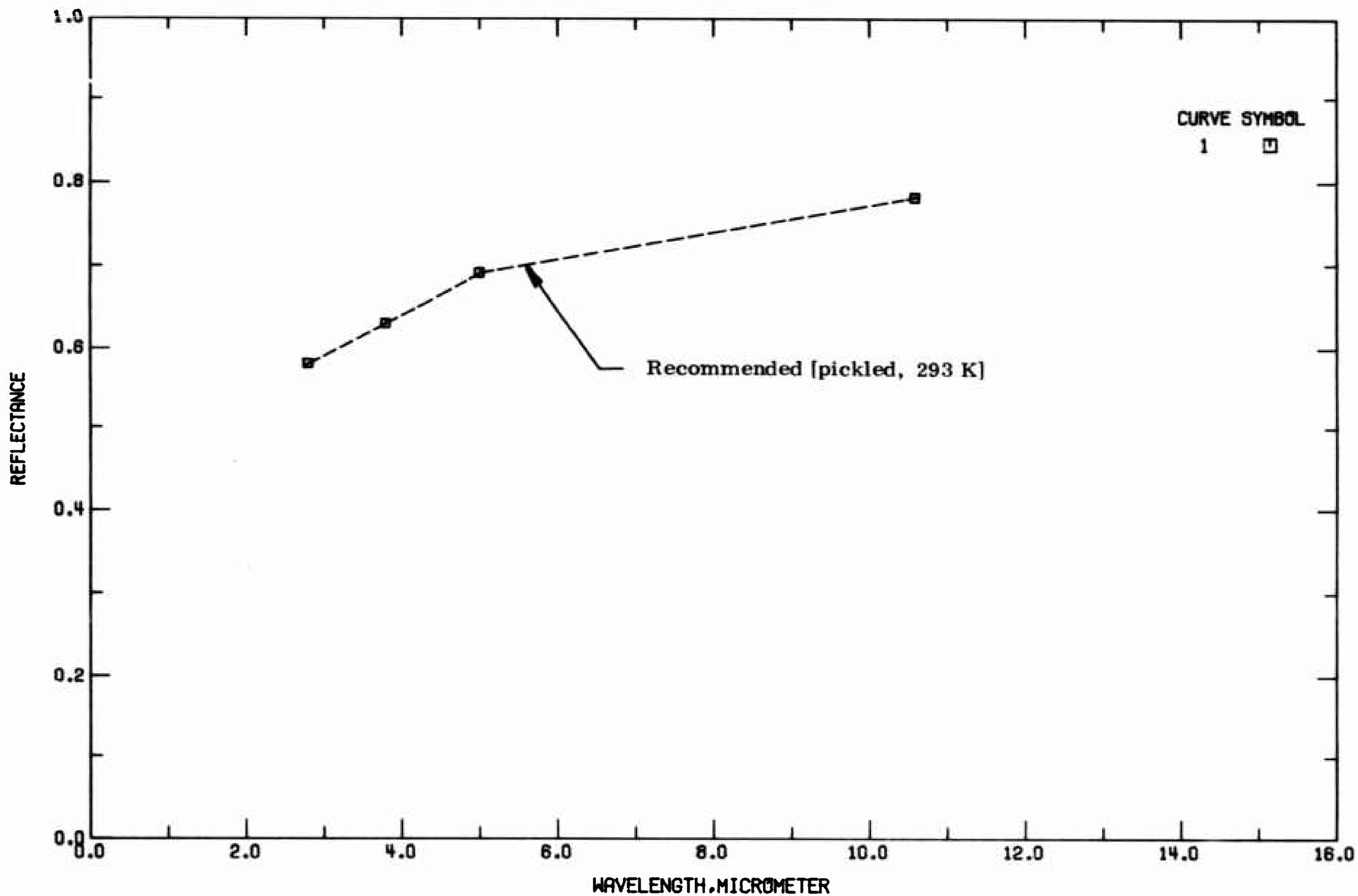


FIGURE 4-8. RECOMMENDED ANGULAR SPECTRAL REFLECTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE).

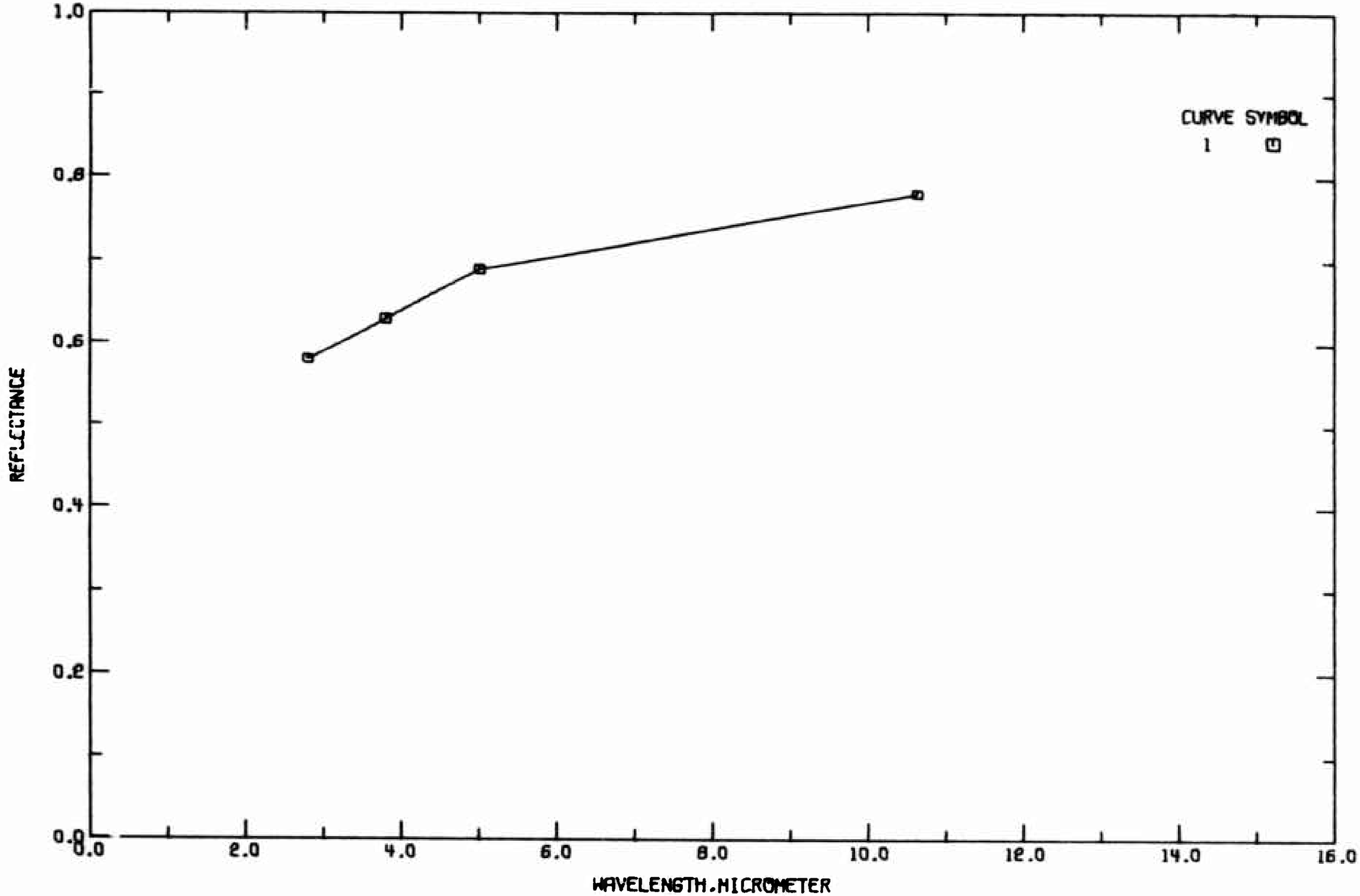


FIGURE 4-9. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE).

TABLE 4-13. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF TITANIUM ALLOY Ti-6Al-4V (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00001	Grimm, T.C. and Fannin, E.R.	1972	2.8-10.6	293		Pickled Ti-6Al-4V alloy, 40 mil. thickness; θ = 45°.

TABLE 4-14. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ
CURVE 1	
T = 293.	
2.8	0.58
3.8	0.63
5.8	0.69
10.6	0.78

g. Normal Spectral Absorptance (Wavelength Dependence)

There are 16 sets of experimental data available for the wavelength dependence (2.8 μm) of the normal spectral absotprance of Titanium Alloy Ti-6Al-4V under various surface conditions. These are tabulated in Table 4-17 and shown in Figure 4-11.

(1) 0.032 μm Finish Alloy

The recommended values tabulated in Table 4-15 and shown in Figure 4-10 calculated from the normal spectral emittance data on the identical material are considered accurate to about ± 15% over the entire wavelength range (see Section 4.5.a).

(2) Oxidized Titanium Alloy Ti-6Al-4V

The recommended values tabulated in Table 4-15 and shown in Figure 4-10 calculated from the normal spectral emittance data on the identical material are considered accurate to about ± 15% over entire wavelength range (see Section 4.5.a).

(3) Anodized Titanium Alloy Ti-6Al-4V

The recommended values for chromic acid anodized surface and tabulated in Table 4-15 and shown in Figure 4-10 calculated from the normal spectral emittance data on the identical material are considered accurate to about ± 15% over the entire wavelength region (see Section 4.1.c and 4.5.a).

TABLE 4-15. RECOMMENDED NORMAL SPECTRAL AESORPTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α
0.032 μm FINISH ALLOY T = 293		0.032 μm FINISH ANODIZED T = 700		OXIDIZED HEATED IN AIR T = 700	
0.4	0.657	2.8	0.798	2.8	0.778
0.5	0.639	3.0	0.785	3.0	0.764
1.0	0.577	3.5	0.758	3.5	0.733
1.5	0.535	3.8	0.747	3.8	0.714
2.0	0.503	4.0	0.744	4.0	0.700
2.5	0.474	4.5	0.740	4.5	0.672
2.8	0.460	5.0	0.738	5.0	0.646
3.0	0.450	5.5	0.735	5.5	0.624
3.5	0.429	6.0	0.734	6.0	0.607
3.8	0.418	6.3	0.730	6.5	0.595
4.0	0.411	6.5	0.726	7.0	0.584
4.5	0.396	6.6	0.720	7.5	0.580
5.0	0.384	6.8	0.691	8.0	0.575
5.5	0.374	7.0	0.646	8.5	0.574
6.0	0.365	7.2	0.616	9.0	0.572
6.5	0.358	7.4	0.604	9.5	0.571
7.0	0.351	7.5	0.603	10.0	0.570
7.5	0.346	7.6	0.607	10.5	0.570
8.0	0.340	7.8	0.646	10.6	0.570
8.5	0.335	8.0	0.746		
9.0	0.330	8.2	0.868		
9.5	0.326	8.4	0.915		
10.0	0.322	8.5	0.928		
10.5	0.318	8.7	0.938		
10.6	0.317	9.0	0.934		
11.0	0.314	9.5	0.923		
11.5	0.308	10.0	0.920		
12.0	0.304	10.5	0.924		
12.5	0.300	11.0	0.929		
13.0	0.295	11.5	0.935		
13.5	0.292	12.0	0.939		
14.0	0.288	12.5	0.940		
14.5	0.284	13.0	0.933		
15.0	0.280	13.5	0.919		
		14.0	0.903		
		14.5	0.894		
		15.0	0.864		

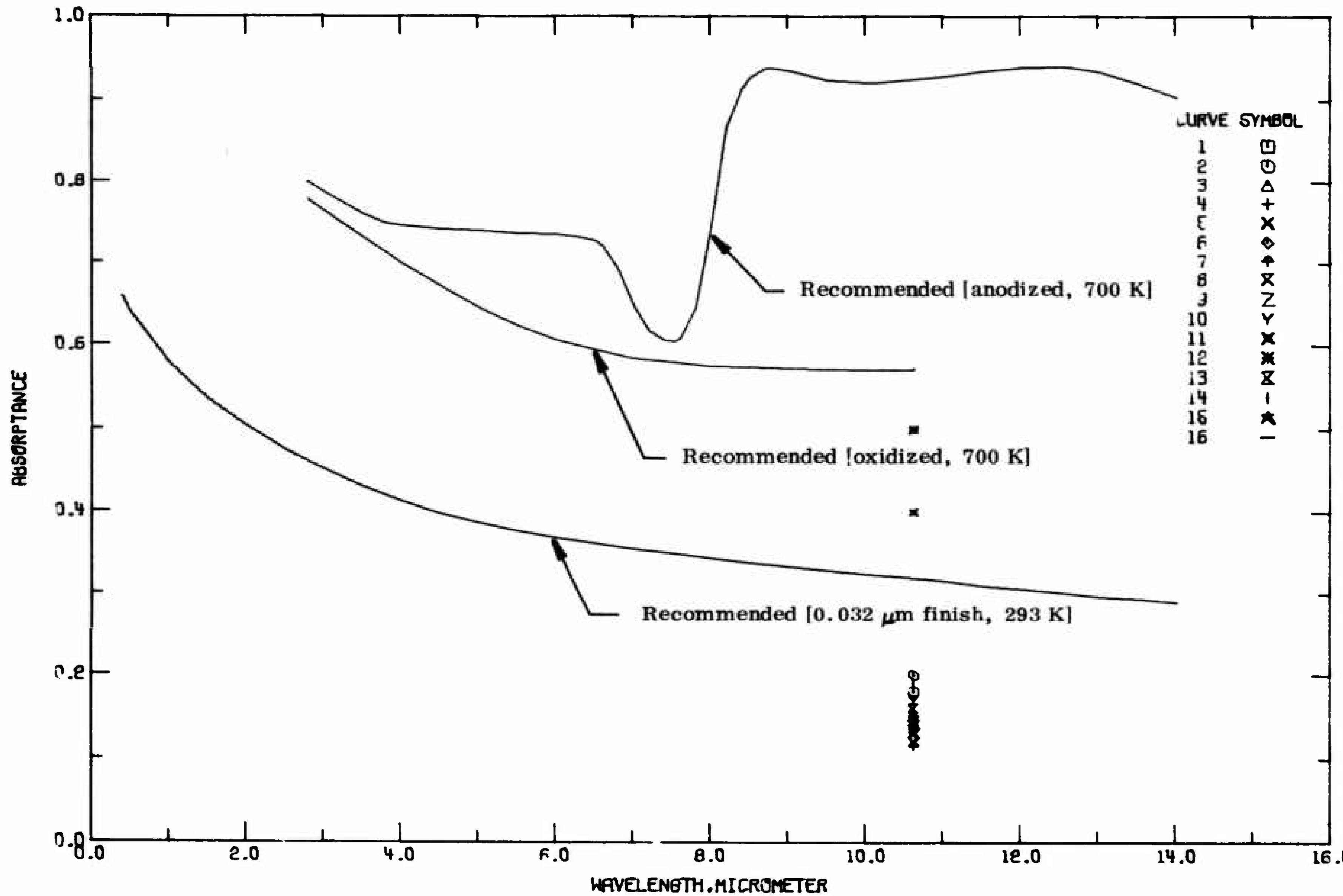


FIGURE 4-10. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE).

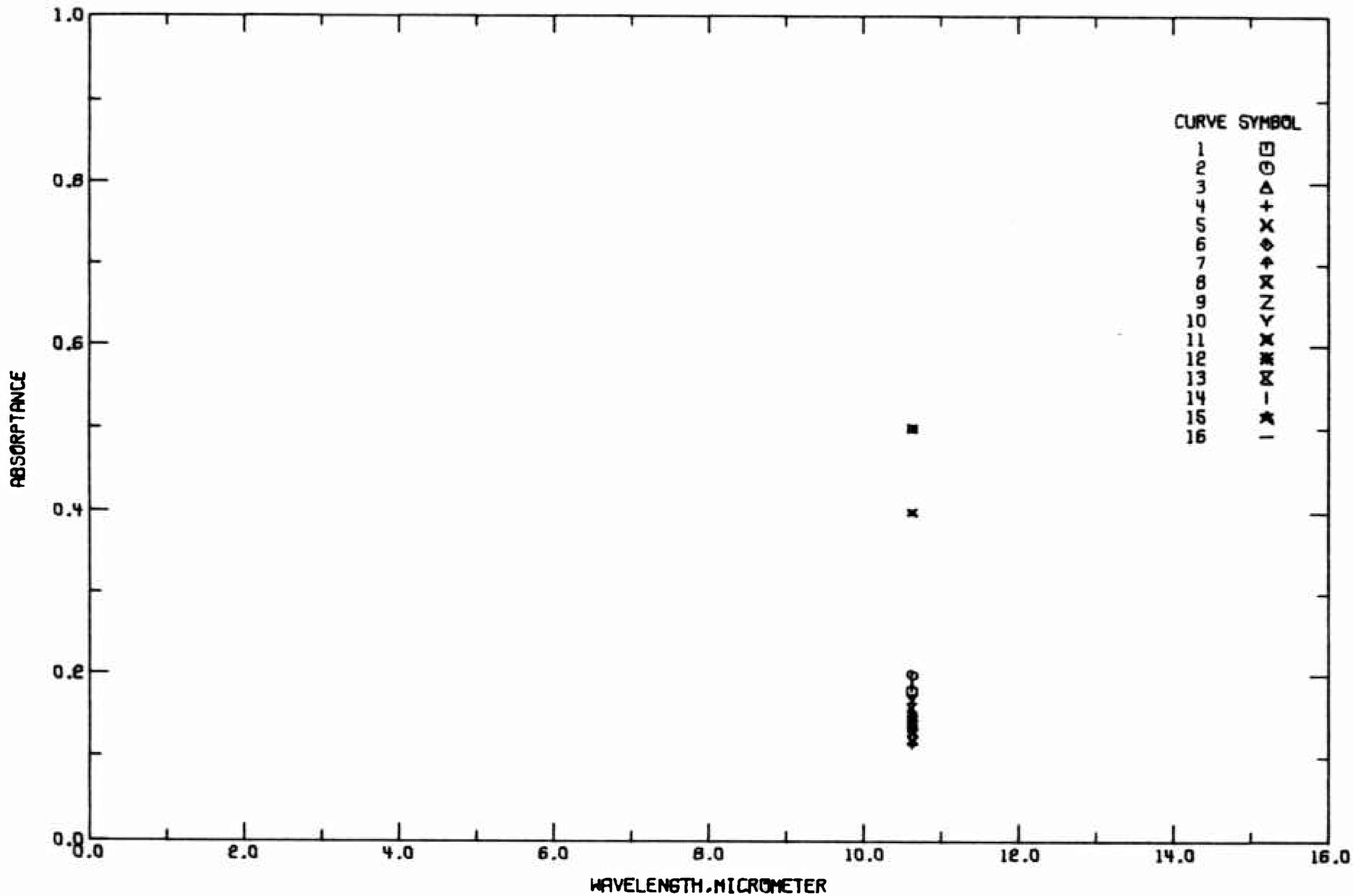


FIGURE 4-11. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE).

TABLE 4-16. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF TITANIUM ALLOY Ti-6Al-4V (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Specimen from the Rodney Metals, 4 mil.
2	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen except values for this and curves 4, 6, 8, 10, 12, 14, and 16 are calculated from reflectance data.
3	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Specimen from the Rodney Metals, mechanically polished.
4	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen.
5	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Specimen from the Rodney Metals, 10 mil.
6	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen.
7	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen except mechanically polished.
8	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen.
9	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the specimen from curve 3 except chemically milled.
10	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen.
11	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the specimen from curve 3 except sand blasted.
12	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen.
13	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Specimen from the Timet Corp.; 15 mil.
14	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen.
15	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen except mechanically polished.
16	A00003	Reichman, J. and Leib, K.	1973	10.6	293		Similar to the above specimen.

TABLE 4-17. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α
CURVE 1 T = 293.		CURVE 9 T = 293.	
10.6	0.180	10.6	0.140
CURVE 2 T = 293.		CURVE 10 T = 293.	
10.6	0.200	10.6	0.170
CURVE 3 T = 293.		CURVE 11 T = 293.	
10.6	0.140	10.6	0.400
CURVE 4 T = 293.		CURVE 12 T = 293.	
10.6	0.150	10.6	0.500
CURVE 5 T = 293.		CURVE 13 T = 293.	
10.6	0.120	10.6	0.160
CURVE 6 T = 293.		CURVE 14 T = 293.	
10.6	0.150	10.6	0.190
CURVE 7 T = 293.		CURVE 15 T = 293.	
10.6	0.115	10.6	0.130
CURVE 8 T = 293.		CURVE 16 T = 293.	
10.6	0.145	10.6	0.145

h. Normal Spectral Absorptance (Temperature Dependence)

There is only one set of data located for the temperature dependence (300-800 K) of the normal spectral absorptance of Titanium Alloy Ti-6Al-4V. This is tabulated in Table 4-19 and shown in Figure 4-12. These values were calculated using the Hagen-Ruben relationship. Due to lack of experimental evidence to support these calculations, no recommendations were made.

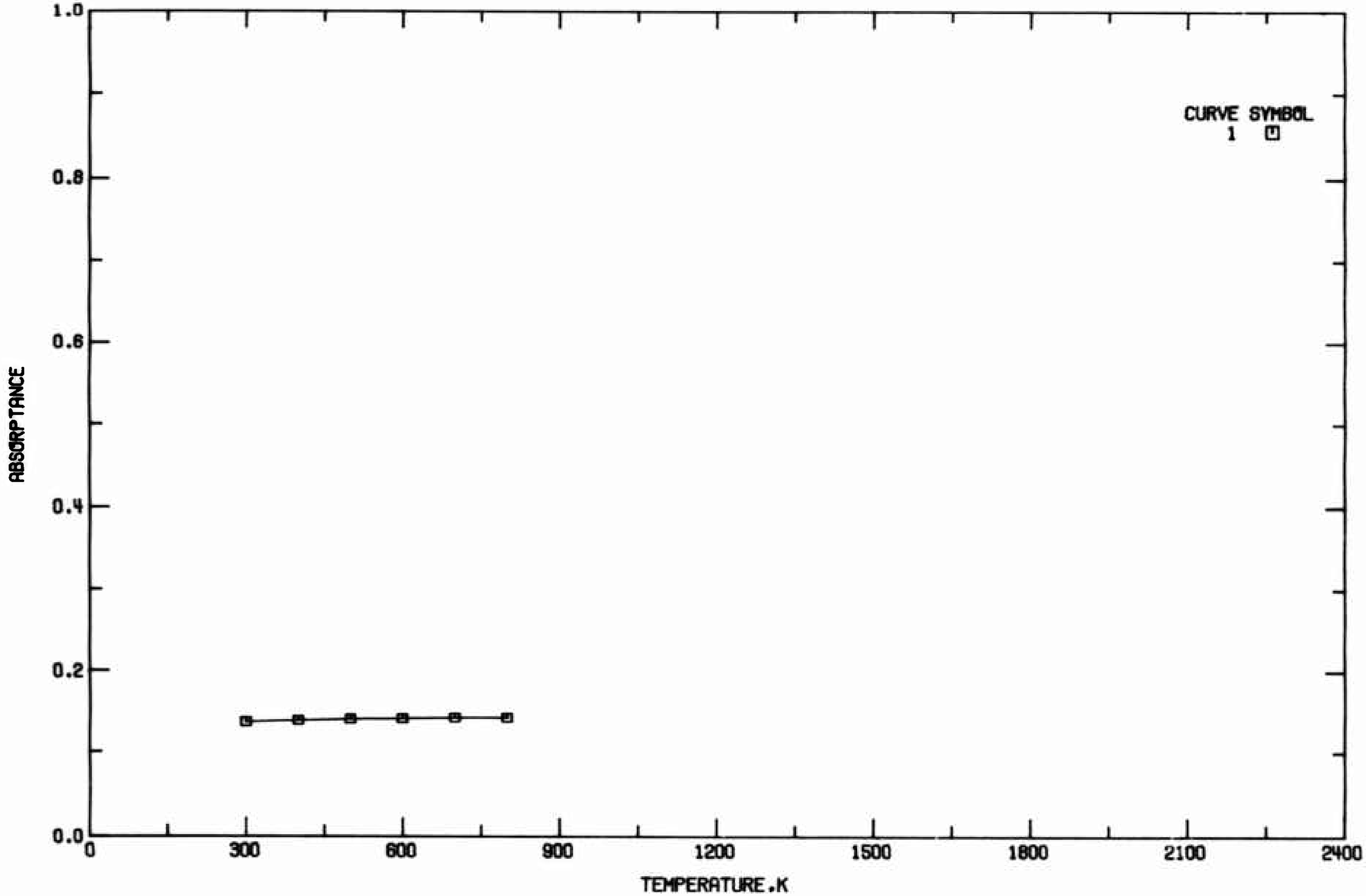


FIGURE 4-12. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF TITANIUM ALLOY TI-6AL-4V (TEMPERATURE DEPENDENCE).

TABLE 4-18. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF TITANIUM ALLOY Ti-6Al-4V (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	E66194	Cunningham, S.S. and Laughlin, W.T.	1974	10.6	300-800		Calculated from Hagen-Rubens relation.

TABLE 4-19. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF TITANIUM ALLOY TI-6AL-4V (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α
CURVE 1 λ = 10.6	
300.	0.136
400.	0.138
500.	0.140
600.	0.141
700.	0.142
800.	0.142

i. Angular Spectral Absorptance (Wavelength Dependence)

There are no experimental data available for this subproperty. The recommended values tabulated in Table 4-20 and shown in Figure 4-13 calculated from the recommended angular spectral emittance for the identical material are considered accurate to within ±15% at the reported wavelengths (see Section 4.5.c).

TABLE 4-20. RECOMMENDED ANGULAR SPECTRAL ABSORPTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α
PICKLED ALLOY T = 293	
2.8	0.42
3.8	0.37
5.0	0.31
10.6	0.22

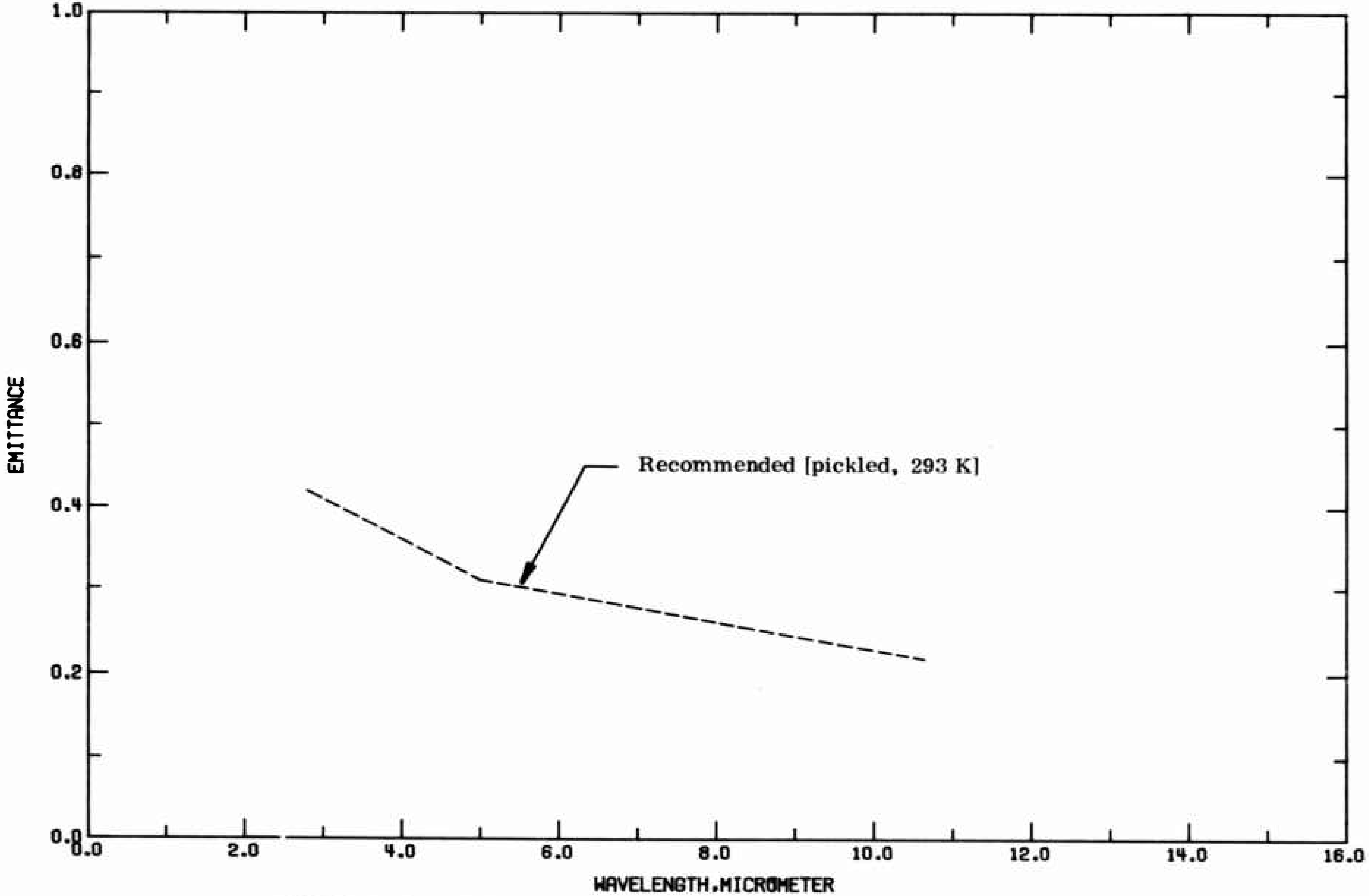


FIGURE 4-13. RECOMMENDED ANGULAR SPECTRAL ABSORPTANCE OF TITANIUM ALLOY TI-6AL-4V (WAVELENGTH DEPENDENCE).

j. Transmittance

Although it is true that metals and alloys in the form of extremely thin films may be transparent for a wide wavelength range, they are opaque if the thickness is greater than several hundred angstroms.

As an aircraft/spacecraft structural material, this alloy is not used in the form of extremely thin films and therefore is opaque; that is, its transmittance is zero.

4.5. Hadfield Manganese Steel

Hadfield manganese steel is an extremely tough nonmagnetic austenitic alloy. It was named after its inventor Sir Robert Abbott Hadfield (1858-1940), an English metallurgist, who was knighted in 1908 for his discovery of this steel in 1883 and many other metallurgical discoveries and inventions. This steel has a nominal composition of 10-14% Mn, 1.0-1.4% C, 0.1-0.3% Si, 0.1% P, and balance Fe. The melting range of this steel is estimated to be about 1470 to 1480 K. This steel is characterized by its high strength, high ductility, and excellent resistance to wear. In the form of castings or of rolled shapes, it serves many industrial requirements economically and has built up an enviable record as the outstanding material for resisting severe service that combines abrasion and heavy impact.

No information on the thermal radiative properties of this or other similar alloy was uncovered from the search of literature. Consequently, tabulation or recommendation of the thermal radiative properties of this alloy is not possible at this time. However, since a metal with thickness greater than several hundred angstroms is opaque, it can be safely stated that the transmittance of this alloy is zero in its bulk form for general applications.

4.6. Aluminum Oxide

The specific type of aluminum oxide for which evaluated data was requested is Wesgo Al-300 which is a dense, vacuum-tight alumina manufactured by the Western Gold and Platinum Company of Belmont, California [A00015]. Wesgo Al-300 contains 97.6% aluminum oxide and has a density of 3.76 g cm^{-3} which is about 95% of the theoretical value, although the manufacturer claims zero porosity. A 1/16 in. flat specimen of this material is white and translucent. The hardness is 75 (Rockwell 45N). The maximum working temperature is 1923 K while the melting point of pure alumina has been reported around 2315 to 2320 K [A00017]. Wesgo Al-300 is made by compacting at pressures higher than conventionally used. Its properties including high abrasion resistance, high thermal conductivity, and excellent dielectric characteristics lead to its use as R.F. windows, high voltage insulators, and vacuum tube envelopes.

A search of the technical literature did not turn up any data on the thermal radiative or optical properties of Wesgo Al-300. Therefore, with no specific data on Wesgo Al-300, no evaluated values can be given for it. However, to give some indication of the thermal radiative properties of alumina it was decided to give evaluated values, where the quantity and quality of data warrants it, for an alumina which has a purity close to Wesgo Al-300. Coors AD 99 is 99% pure aluminum oxide, while Coors AD 96 is 96% pure aluminum oxide and these specific materials are higher and lower in purity, respectively, than the 97.6% purity of Wesgo Al-300. It should be emphasized that any evaluated data for Coors is not a substitute for actual measurements on Wesgo Al-300 and is only given to give an indication of the behavior of another specific alumina. Because evaluated data was requested for Wesgo Al-300, data was generally not extracted for ruby or sapphire.

a. Normal Spectral Emittance (Wavelength Dependence)

A total of 86 sets of experimental data were located for the wavelength dependence of the normal spectral emittance of aluminum oxide as listed in Table 6-3 and shown in Figures 6-1 through 6-6. Curves 1 through 30 are shown in Figures 6-1 and 6-4. Curves 31 through 60 are shown in Figures 6-2 and 6-5. Curves 61 through 86 are shown in Figures 6-3 and 6-6. Specimen characterization and measurement information for the data are given in Table 8-2.

There is no data specifically for Wesgo Al-300, however, there are data for Coors AD 99 and Coors AD 96 which have a purity higher and lower, respectively, compared to Wesgo Al-300. Folweiler [T29570] (curves 22-26) has measured the normal spectral emittance of Coors AD 96. The data was presented in tabular form and for widely spaced

wavelengths leading to the conclusion that giving evaluated values is not justified. Data for Coors AD 99 was presented by Folweiler [T29570] (curves 17-21), Blau, et al. [T16606] (curves 3, 4, and 7), and Blau and Jasperse [T32045] (curve 62). The data for curves 17-20 was presented in tabular form with the remaining curves for Coors AD 99 given in graphical form. Curve 20 at 1423 K gives supporting evidence to curve 21, also at 1423 K, given in graphical form. These two curves form the basis for provisonal values for the normal spectral emittance of Coors AD 99 at 1423 K with the values listed in Table 6-1 and shown in Tables 6-1, 6-2, and 6-3. The provisional curve continues only to 11 μm to keep the uncertainty to a 15% value. Curves 4 and 62 for a temperature of 1303 K are very similar to each other and form the basis of the provisional values for Coors AD 99 at 1303 K with the values listed in Table 6-1 and shown in Tables 6-1, 6-2, and 6-3; the uncertainty for this curve is 15%. Beyond 4.8 μm both provisional curves are the same since the stated uncertainty and the curves forming the basis of the provisional values do not justify separate provisional curves.

TABLE 6-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE(COORS AD 99) (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
T = 1303		T = 1303 (CONT.)		T = 1303 (CONT.)		T = 1423		T = 1423 (CONT.)		T = 1423 (CONT.)	
2.0	0.432	5.9	0.926	9.8	0.983	1.0	0.226	5.0	0.798	8.9	0.985
2.1	0.436	6.0	0.936	9.9	0.983	1.1	0.226	5.1	0.820	9.0	0.985
2.2	0.439	6.1	0.943	10.0	0.982	1.2	0.226	5.2	0.839	9.1	0.985
2.3	0.443	6.2	0.950	10.1	0.980	1.3	0.227	5.3	0.857	9.2	0.985
2.4	0.448	6.3	0.956	10.2	0.979	1.4	0.228	5.4	0.871	9.3	0.985
2.5	0.452	6.4	0.962	10.3	0.976	1.5	0.228	5.5	0.885	9.4	0.985
2.6	0.457	6.5	0.966	10.4	0.974	1.6	0.229	5.6	0.897	9.5	0.984
2.7	0.462	6.6	0.970	10.5	0.970	1.7	0.230	5.7	0.908	9.6	0.984
2.8	0.467	6.7	0.974	10.6	0.966	1.8	0.232	5.8	0.918	9.7	0.984
2.9	0.472	6.8	0.976	10.7	0.962	1.9	0.233	5.9	0.926	9.8	0.983
3.0	0.478	6.9	0.978	10.8	0.957	2.0	0.235	6.0	0.936	9.9	0.983
3.1	0.484	7.0	0.980	10.9	0.951	2.1	0.238	6.1	0.943	10.0	0.982
3.2	0.490	7.1	0.981	11.0	0.943	2.3	0.241	6.2	0.950	10.1	0.980
3.3	0.498	7.2	0.982			2.4	0.244	6.3	0.956	10.2	0.979
3.4	0.505	7.3	0.983			2.5	0.246	6.4	0.962	10.3	0.976
3.5	0.513	7.4	0.984			2.6	0.250	6.5	0.966	10.4	0.974
3.6	0.522	7.5	0.985			2.7	0.254	6.6	0.970	10.5	0.970
3.7	0.532	7.6	0.985			2.8	0.259	6.7	0.974	10.6	0.966
3.8	0.543	7.7	0.985			2.9	0.265	6.8	0.976	10.7	0.962
3.9	0.556	7.8	0.986			3.0	0.274	6.9	0.978	10.8	0.957
4.0	0.570	7.9	0.986			3.1	0.283	7.0	0.980	10.9	0.951
4.1	0.586	8.0	0.986			3.2	0.294	7.1	0.981	11.0	0.943
4.2	0.604	8.1	0.986			3.3	0.306	7.2	0.982		
4.3	0.625	8.2	0.986			3.4	0.320	7.3	0.983		
4.4	0.649	8.3	0.986			3.5	0.336	7.4	0.984		
4.5	0.674	8.4	0.986			3.6	0.354	7.5	0.985		
4.6	0.699	8.5	0.985			3.7	0.376	7.6	0.985		
4.7	0.725	8.6	0.985			3.8	0.399	7.7	0.985		
4.8	0.746	8.7	0.985			3.9	0.428	7.8	0.986		
4.9	0.774	8.8	0.985			4.0	0.458	7.9	0.986		
5.0	0.798	8.9	0.985			4.1	0.488	8.0	0.986		
5.1	0.820	9.0	0.985			4.2	0.522	8.1	0.986		
5.2	0.839	9.1	0.985			4.3	0.560	8.2	0.986		
5.3	0.857	9.2	0.985			4.4	0.600	8.3	0.986		
5.4	0.871	9.3	0.985			4.5	0.640	8.4	0.986		
5.5	0.885	9.4	0.985			4.6	0.678	8.5	0.985		
5.6	0.897	9.5	0.984			4.7	0.714	8.6	0.985		
5.7	0.908	9.6	0.984			4.8	0.746	8.7	0.985		
5.6	0.918	9.7	0.984			4.9	0.774	8.8	0.985		

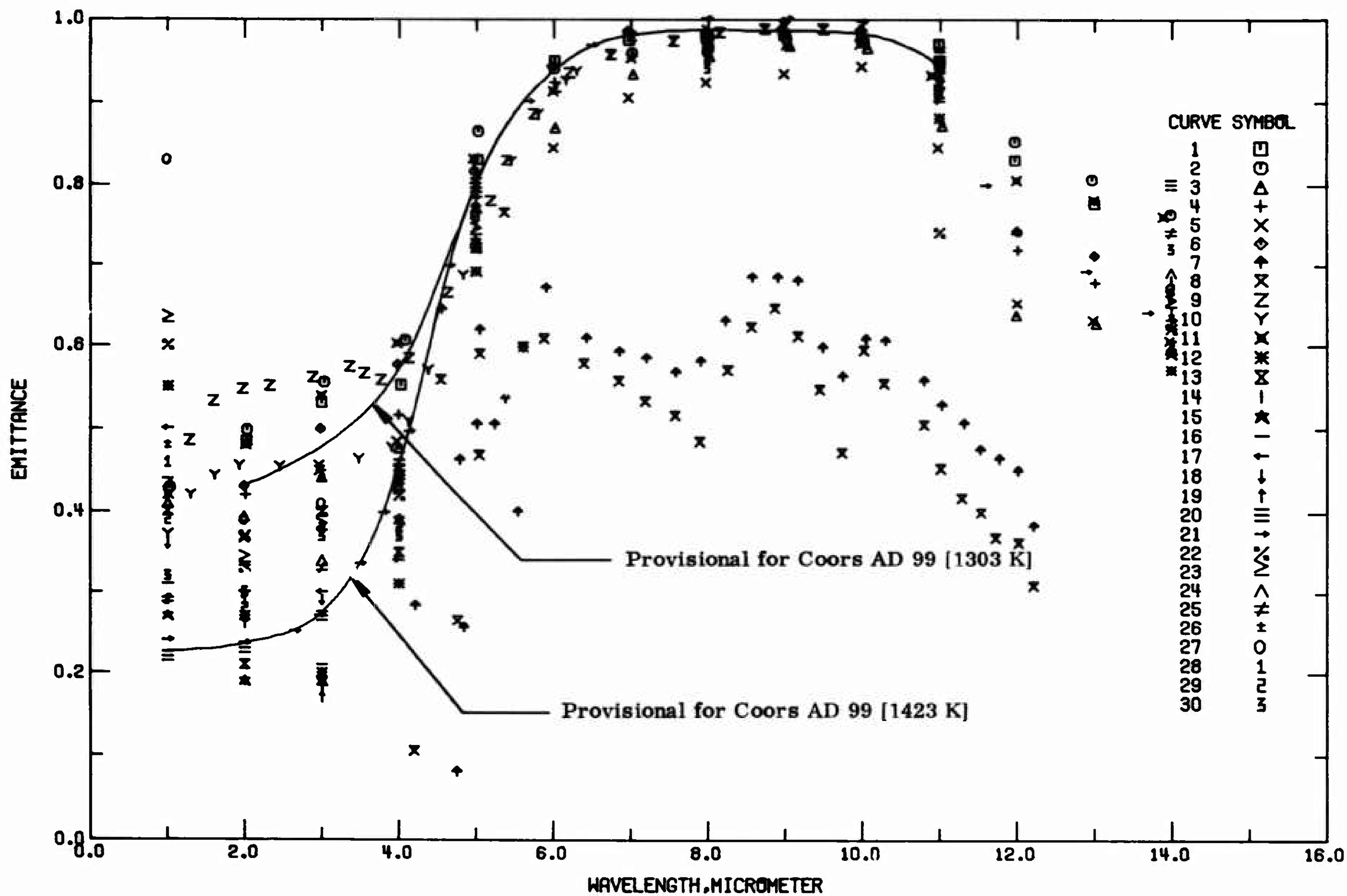


FIGURE 6-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE).

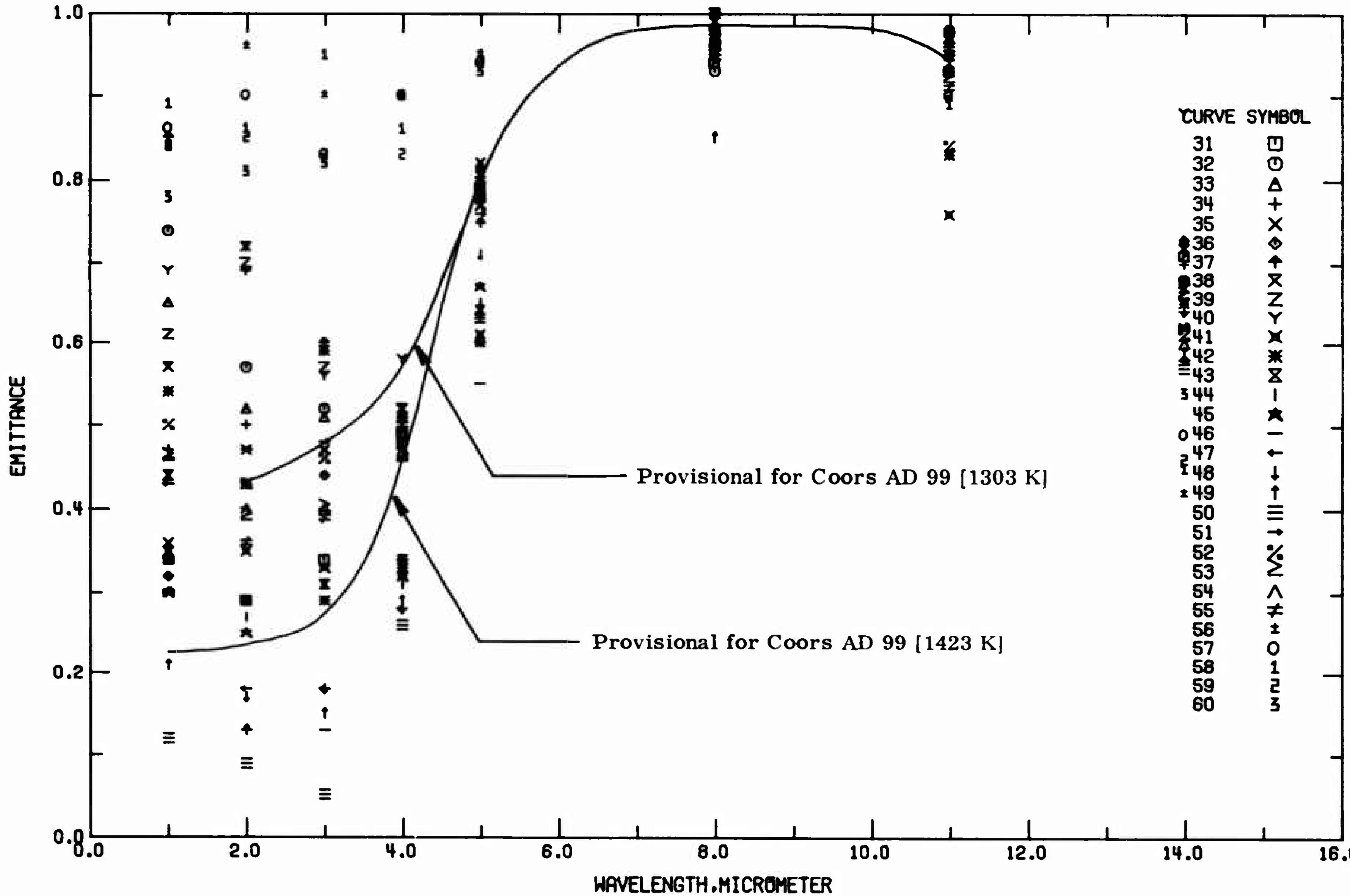


FIGURE 6-2. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE).

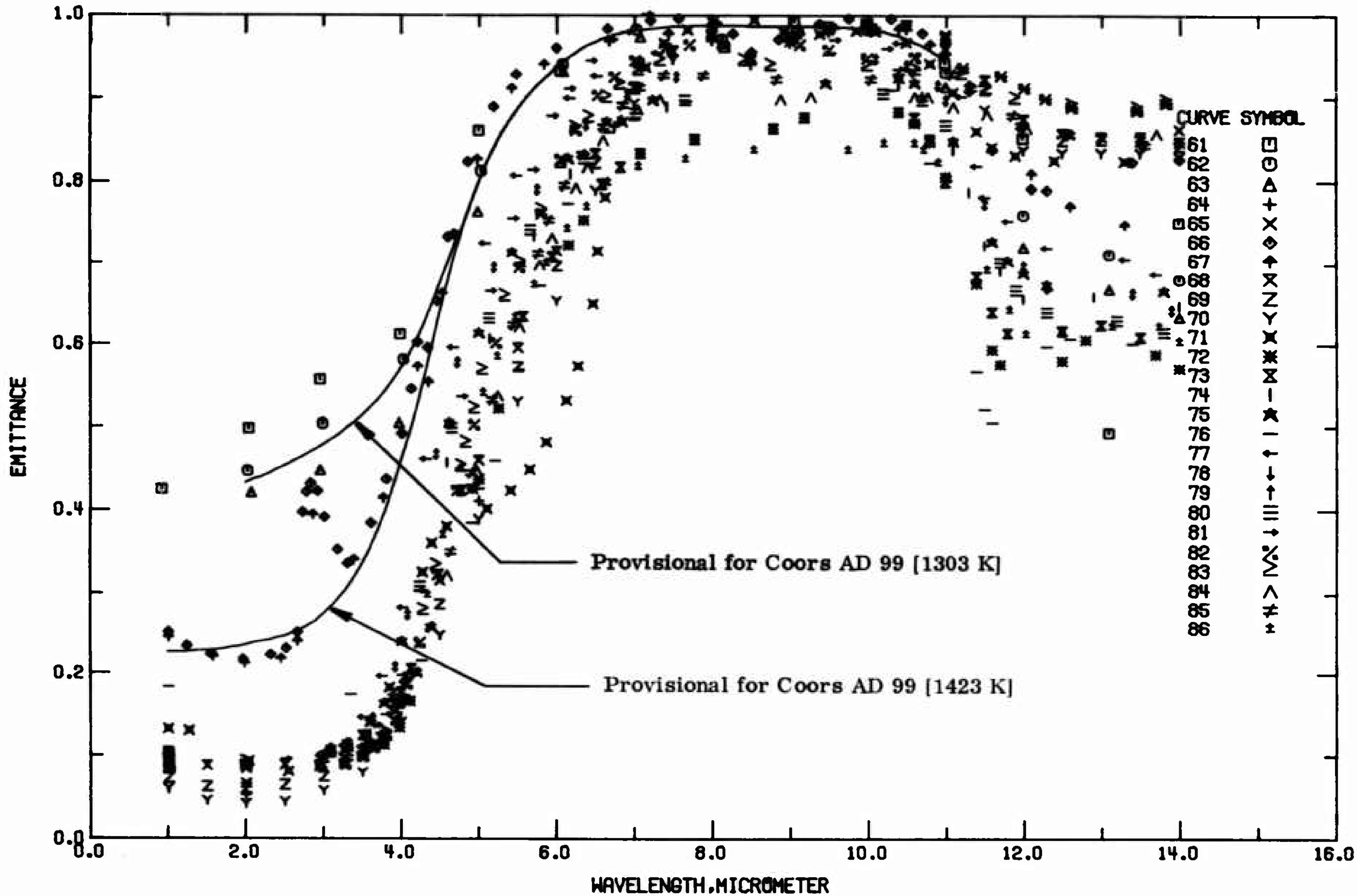


FIGURE 6-3. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE).

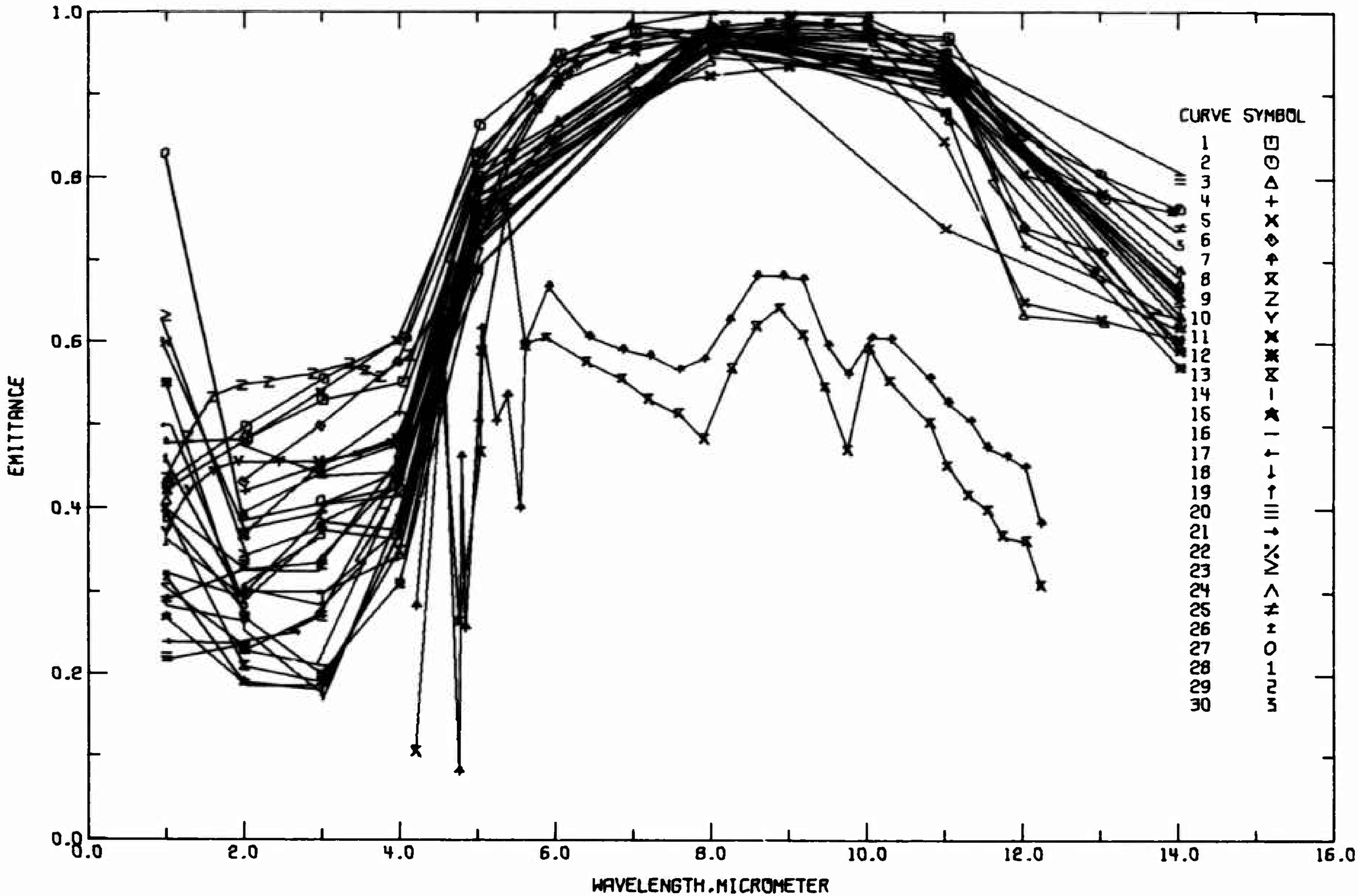


FIGURE 6-4. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE).

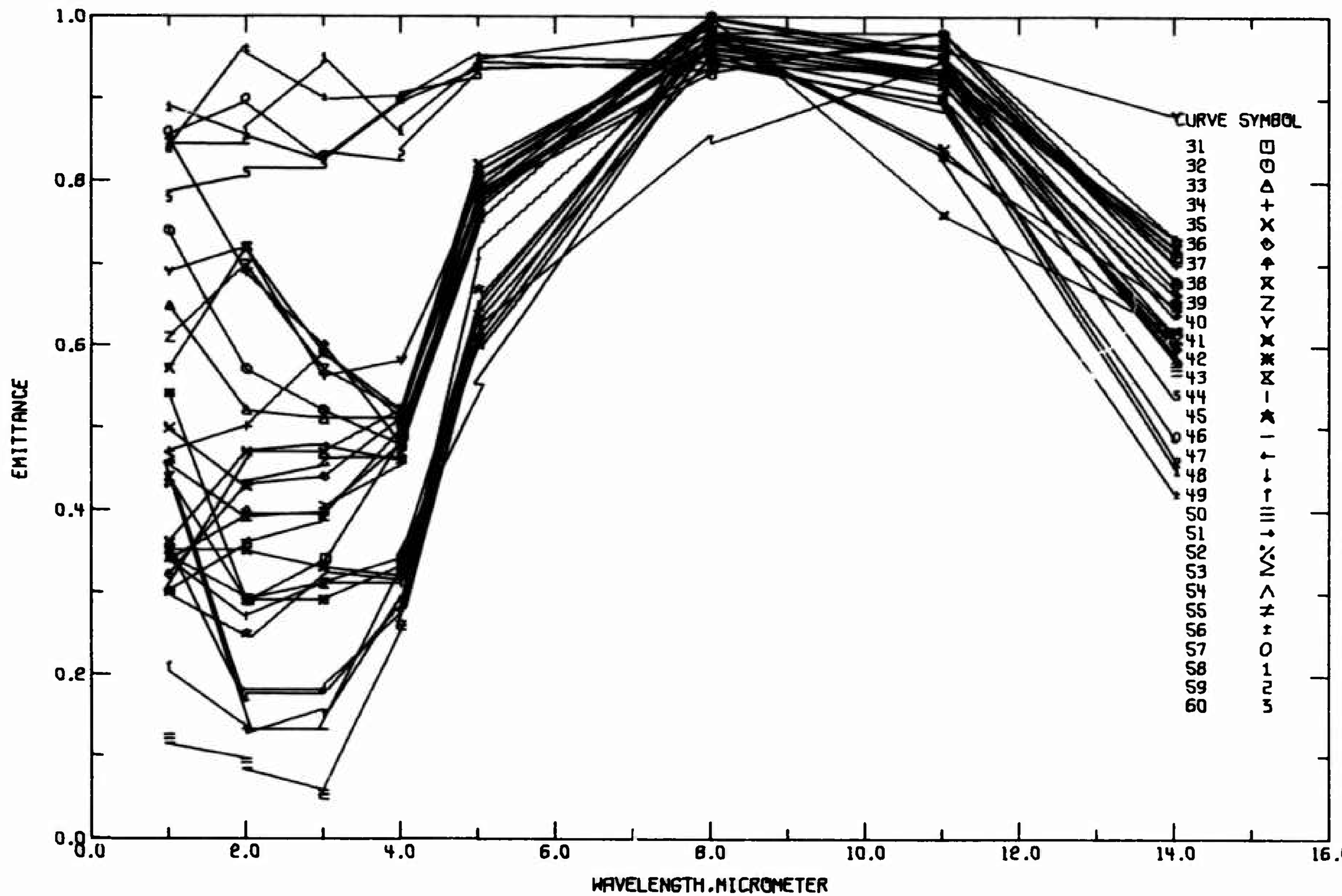


FIGURE 6-5. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE).

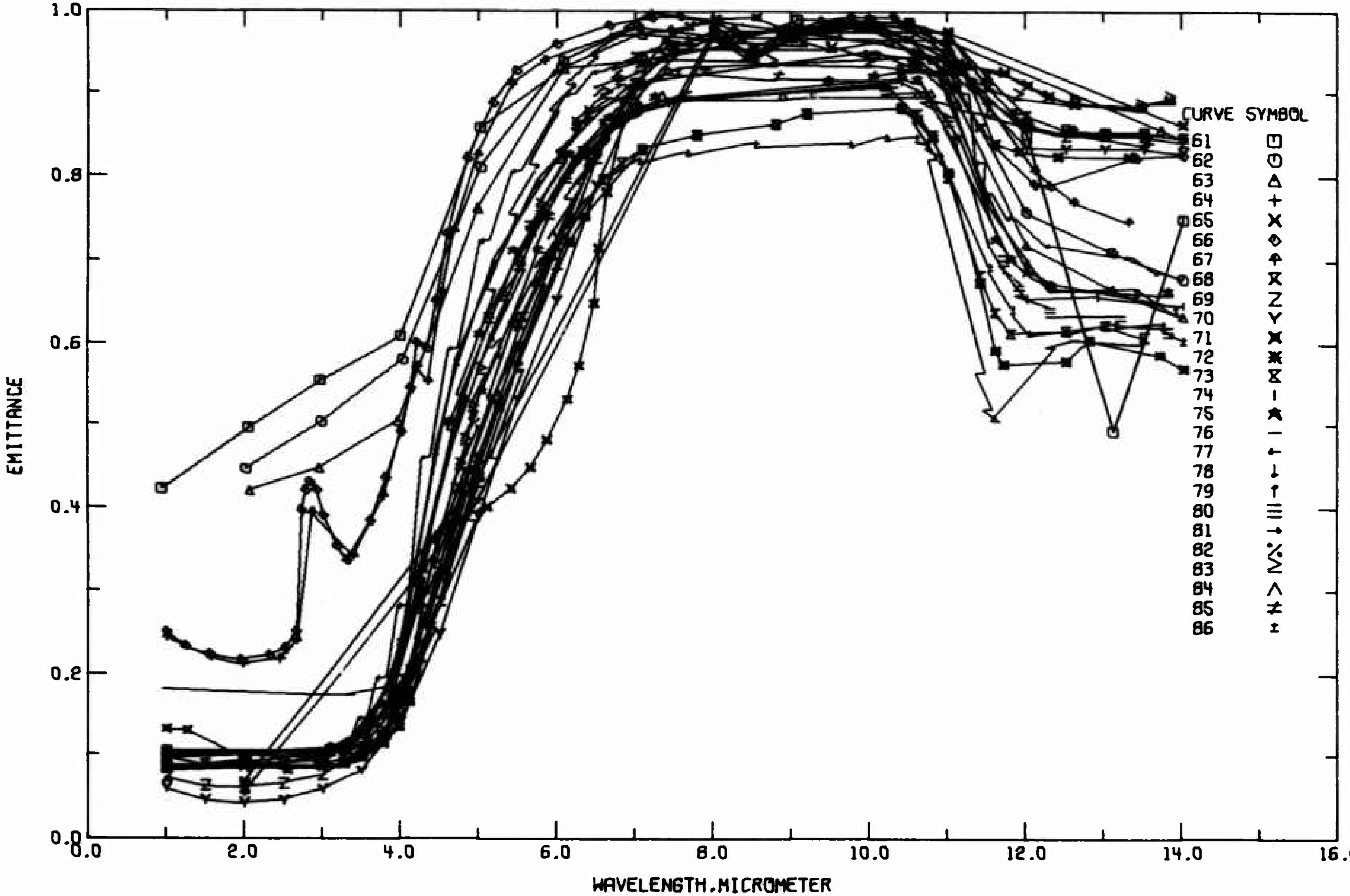


FIGURE 6-6. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE).

TABLE 6-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T16606	Blau, H.H., Jr., Marsh, J.B., Martin, W.S., Jasperse, J.R., and Chaffee, E.	1960	2.0-14	873	Coors AD 85	85 Al_2O_3; measured in air; measurements made with Perkin-Elmer Model 12c infrared spectrometer with sodium chloride prism; data from figure; $\theta' = 0°$; reported error ±4%.
2	T16606	Blau, H.H., Jr., et al.	1960	1.0-14	1303	Coors AD 85	Similar to the above specimen.
3	T16606	Blau, H.H., Jr., et al.	1960	2.0-14	873	Coors AD 99	Similar to the above specimen except 99 Al_2O_3.
4	T16606	Blau, H.H., Jr., et al.	1960	2.0-14	1303	Coors AD 99	Similar to the above specimen.
5	T16606	Blau, H.H., Jr., et al.	1960	2.0-14	873	Norton TWA No. 2, A402	Similar to the above specimen except 98.56 Al_2O_3.
6	T16606	Blau, H.H., Jr., et al.	1960	2.0-14	1323	Norton TWA No. 2, A402	Similar to the above specimen.
7	T16606	Blau, H.H., Jr., et al.	1960	4.2-12	560	Coors AD 99	99 Al_2O_3; specimen heated in air; solar furnace used to measure spectral reflectance; data not accurate; data from figure; $\theta' = 0°$.
8	T16606	Blau, H.H., Jr., et al.	1960	4.2-12	560	Norton TWA No. 2, A402	Similar to the above specimen except 98.56 Al_2O_3.
9	T35902	Grenis, A.F. and Levitt, A.P.	1965	1.0-10	1300		98.55 Al_2O_3, 0.58 SiO_2, 0.31 NaO_2, 0.23 MgO, 0.19 CaO, 0.10 Fe_2O_3, and 0.04 TiO_2; gamma type crystal form; from Norton Refractories; surface roughness 225 μ in.; flame sprayed coating 12 mils thick on mild steel base; density of coating 3.3 g cm^{-3}, porosity of coating 8-12%; measured in vacuum of 35 to 50 μ pressure; $\theta' = 0°$.
10	T35902	Grenis, A.F. and Levitt, A.P.	1965	1.0-10	1300		Similar to the above specimen except surface finished with polishing papers; flame sprayed coating 15 mils thick on mild steel base.
11	T21923	Stamp, W.S. and Wade, W.R.	1962	1.0-15	923	Norton 5190 alumina	Smooth values from figure; $\theta' \sim 0°$; reported error ±5%.
12	T29570	Folweiler, R.C.	1964	1-14	814	Coors AD 995 alumina	99.5 Al_2O_3; rotating specimen in furnace used in conjunction with Baird-Atomic infrared spectrometer, model NK-1A, for emittance determination; $\theta' \sim 0°$; reported error 10%.
13	T29570	Folweiler, R.C.	1964	1-14	1055	Coors AD 995 alumina	The above specimen.
14	T29570	Folweiler, R.C.	1964	1-14	1227	Coors AD 995 alumina	The above specimen.
15	T29570	Folweiler, R.C.	1964	1-14	1410	Coors AD 995 alumina	The above specimen.
16	T29570	Folweiler, R.C.	1964	1-14	1592	Coors AD 995 alumina	The above specimen.
17	T29570	Folweiler, R.C.	1964	1-14	813	Coors AD 99 alumina	Similar to the above specimen except 99 Al_2O_3.
18	T29570	Folweiler, R.C.	1964	1-14	1053	Coors AD 99 alumina	The above specimen.

TABLE 6-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, µm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
19	T29570	Folweiler, R.C.	1964	1-14	1188	Coors AD 99 alumina	The above specimen.
20	T29570	Folweiler, R.C.	1964	1-14	1423	Coors AD 99 alumina	The above specimen.
21	T29570	Folweiler, R.C.	1964	1.0-15	1423	Coors AD 99 alumina	Similar to the above specimen except smooth values from figure.
22	T29570	Folweiler, R.C.	1964	1-14	822	Coors AD 96 alumina	96 Al_2O_3; $\theta' \sim 0°$; reported error 10%.
23	T29570	Folweiler, R.C.	1964	1-14	1063	Coors AD 96 alumina	The above specimen.
24	T29570	Folweiler, R.C.	1964	1-14	1183	Coors AD 96 alumina	The above specimen.
25	T29570	Folweiler, R.C.	1964	1-14	1401	Coors AD 96 alumina	The above specimen.
26	T29570	Folweiler, R.C.	1964	1-14	1526	Coors AD 96 alumina	The above specimen.
27	T29570	Folweiler, R.C.	1964	1-14	813	Coors AD 94 alumina	94 Al_2O_3; rotating specimen in furnace used in conjunction with Baird-Atomic infrared spectrometer, model NK-1A, for emittance determination; $\theta' \sim 0°$; reported error 10%.
28	T29570	Folweiler, R.C.	1964	1-14	1035	Coors AD 94 alumina	The above specimen.
29	T29570	Folweiler, R.C.	1964	1-14	1220	Coors AD 94 alumina	The above specimen.
30	T29570	Folweiler, R.C.	1964	1-14	1413	Coors AD 94 alumina	The above specimen.
31	T29570	Folweiler, R.C.	1964	1-14	1591	Coors AD 94 alumina	The above specimen.
32	T29570	Folweiler, R.C.	1964	1-14	811	Coors AD 85 alumina	Similar to the above specimen except 85 Al_2O_3.
33	T29570	Folweiler, R.C.	1964	1-14	1053	Coors AD 85 alumina	The above specimen.
34	T29570	Folweiler, R.C.	1964	1-14	1208	Coors AD 85 alumina	The above specimen.
35	T29570	Folweiler, R.C.	1964	1-14	1413	Coors AD 85 alumina	The above specimen.
36	T29570	Folweiler, R.C.	1964	1-14	1513	Coors AD 85 alumina	The above specimen.
37	T29570	Folweiler, R.C.	1964	1-14	813	Coors AD 96 alumina	1% $CoCO_3$; rotating specimen in furnace used in conjunction with Baird-Atomic infrared spectrometer, model NK-1A, for emittance determination; $\theta' \sim 0°$; reported error 10%.

TABLE 6-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
38	T29570	Folweiler, R.C.	1964	1-14	1053	Coors AD 96 alumina	The above specimen.
39	T29570	Folweiler, R.C.	1964	1-14	1188	Coors AD 96 alumina	The above specimen.
40	T29570	Folweiler, R.C.	1964	1-14	1423	Coors AD 96 alumina	The above specimen.
41	T29570	Folweiler, R.C.	1964	1-14	822	McDanel AP-35 alumina	99 Al_2O_3; slip cast; rotating specimen in furnace used in conjunction with Baird-Atomic infrared spectrometer, model NK-1A, for emittance determinations; $\theta' \sim 0°$; reported error 10%.
42	T29570	Folweiler, R.C.	1964	1-14	1063	McDanel AP-35 alumina	The above specimen.
43	T29570	Folweiler, R.C.	1964	1-14	1183	McDanel AP-35 alumina	The above specimen.
44	T29570	Folweiler, R.C.	1964	1-14	1401	McDanel AP-35 alumina	The above specimen.
45	T29570	Folweiler, R.C.	1964	1-14	1523	McDanel AP-35 alumina	The above specimen.
46	T29570	Folweiler, R.C.	1964	1-14	833	McDanel AP-35 alumina	Similar to the above specimen except isostatically pressed.
47	T29570	Folweiler, R.C.	1964	1-14	1037	McDanel AP-35 alumina	The above specimen.
48	T29570	Folweiler, R.C.	1964	1-14	1208	McDanel AP-35 alumina	The above specimen.
49	T29570	Folweiler, R.C.	1964	1-14	1395	McDanel AP-35 alumina	The above specimen.
50	T29570	Folweiler, R.C.	1964	1-14	1572	McDanel AP-35 alumina	The above specimen; value given in document at 2 μm was 0.9, which is probably an error, 0.09 presumed.
51	T29570	Folweiler, R.C.	1964	1-14	814	McDanel AV-30 alumina	96 Al_2O_3; vitrified alumina; rotating specimen in furnace used in conjunction with Baird-Atomic infrared spectrometer, model NK-1A, for emittance determination; $\theta' \sim 0°$, reported error 10%.
52	T29570	Folweiler, R.C.	1964	1-14	1053	McDanel AV-30 alumina	The above specimen.
53	T29570	Folweiler, R.C.	1964	1-14	1125	McDanel AV-30 alumina	The above specimen.
54	T29570	Folweiler, R.C.	1964	1-14	1408	McDanel AV-30 alumina	The above specimen.
55	T29570	Folweiler, R.C.	1964	1-14	1592	McDanel AV-30 alumina	The above specimen.
56	T29570	Folweiler, R.C.	1964	1-14	813	GE Lucalox alumina	Cold-pressed and sintered; MgO added to control grain growth; rotating specimen in furnace used in conjunction with Baird-Atomic infrared spectrometer, model NK-1A, for emittance determination; $\theta \sim 0°$; reported error 10%.

TABLE 6-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
57	T29570	Folweiler, R.C.	1964	1-14	1034	GE Lucalox alumina	The above specimen.
58	T29570	Folweiler, R.C.	1964	1-14	1220	GE Lucalox alumina	The above specimen.
59	T29570	Folweiler, R.C.	1964	1-14	1413	GE Lucalox alumina	The above specimen.
60	T29570	Folweiler, R.C.	1964	1-14	1595	GE Lucalox alumina	The above specimen.
61	T32045	Blau, H.H., Jr., and Jasperse, J.R.	1964	0.92-14	1303	Coors AD 85	85 Al_2O_3; ultrasonically machined; measured in air; θ' = 0°; reported error ≤4%.
62	T32045	Blau, H.H., Jr., and Jasperse, J.R.	1964	2.0-14	1303	Coors AD 99	Similar to the above specimen except 99 Al_2O_3.
63	T32045	Blau, H.H., Jr., and Jasperse, J.R.	1964	2.1-14	1323	Norton TWA No. 2; A402	Similar to the above specimen except 96.5 Al_2O_3.
64	T38726	Clark, H.E.	1965	2-14	1400		Rotating specimen method with hollow cylinder of 7.94 mm wall thickness and diameter of 2.5 cm rotated at 100 rpm in front of a water cooled viewing port; separation distance between specimen and viewing port 0.127 mm; θ' = 0°.
65	T38726	Clark, H.E.	1965	2-14	1400		Similar to the above specimen except separation distance between specimen and viewing port 0.400 mm.
66	T48368	Richmond, J.C.	1966	1.0-15	1073	AD-5 alumina	Measured at NBS by rotating cylinder method; smooth values from figure; measurement temperature not given explicitly, 1073 K assigned because that figure mentioned in a related context; θ' = 0°.
67	T48368	Richmond, J.C.	1966	1.0-15	1073	AD-5 alumina	The above specimen except grit blasted.
68	T41606	Clark, H.E. and Moore, D.G.	1966	1.0-15	1600		>99 pure, 0.40 Fe_2O_3, 0.10 SiO_2, 0.07 CaO, and 0.02 Na_2O; porosity 30 percent by volume; polycrystal; cylinder, 0.1875 in. wall thickness; outer surface smooth but not polished; sintered at 1865 K for 27 hr; average of two readings on each of three specimens; rotating specimen method used; θ' = 0°.
69	T41606	Clark, H.E. and Moore, D.G.	1966	1.0-15	1400		The above specimen.
70	T41606	Clark, H.E. and Moore, D.G.	1966	1.0-15	1200		The above specimen.
71	T50298	Lewis, B.W., Wade, W.R., Siemp, W.S., and Progar, D.J.	1966	1.0-15	1255		Al_2O_3 pure slab; 8.13 mm thick; smooth values from figure; θ = 0°.
72	T37398	Schatz, E.A., Counts, C.R., III, and Burks, T.L.	1964	1.0-15	885		99.9 pure powder; from Linde Co.; powder 1 μm particle size; sintered 2 hr at 2023 K; measurement made with help of Baird-Atomic Model NK-1 infrared double beam spectrophotometer; smooth values from figure; θ' ~ 0°; reported error ± 5%.
73	T37398	Schatz, E.A., et al.	1964	1.0-15	993		The above specimen.
74	T37398	Schatz, E.A., et al.	1964	1.0-15	1148		The above specimen.
75	T37398	Schatz, E.A., et al.	1964	1.0-15	1273		The above specimen.

TABLE 6-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
76	T37398	Schatz, E.A., Counts, C.R., III, and Burks, T.L.	1964	1.0-15	373		The above specimen; calculated from spectral reflectance.
77	T35840	Schatz, E.A., Alvarez, G.H., Counts, C.R., III, and Hoppke, M.A.	1965	1.0-15	1273		Sintered 1 hr at 1973 K; smooth values from figure; $\theta' = 0°$.
78	T35840	Schatz, E.A., et al.	1965	1.0-15	1273		The above specimen except heated at 1273 K in measuring apparatus for 1 hr total in order to study emittance as a function of time of heating at 1273 K.
79	T35840	Schatz, E.A., et al.	1965	1.0-15	1273		The above specimen except heated at 1273 K in measuring apparatus for 2 hr total.
80	T35840	Schatz, E.A., et al.	1965	1.0-15	1273		The above specimen except heated at 1273 K in measuring apparatus for 4 hr total.
81	T35840	Schatz, E.A., et al.	1965	1.0-15	1273		Sintering conditions: 15 hr at 1273 K; after each sintering operation density measured by mercury displacement; density 1.58 g cm^{-3}; $\theta' = 0°$.
82	T35840	Schatz, E.A., et al.	1965	1.0-15	1273		The above specimen with additional 2 hr at 1373 K (to study effect of sintering, specimen removed from apparatus between measurements and heated at increasingly higher temperature) and density 1.60 g cm^{-3}.
83	T35840	Schatz, E.A., et al.	1965	1.0-15	1273		The above specimen with additional 2 hr at 1473 K and density of 1.65 g cm^{-3}.
84	T35840	Schatz, E.A., et al.	1965	1.0-15	1273		The above specimen with additional 2 hr at 1573 K and density of 1.71 g cm^{-3}.
85	T35840	Schatz, E.A., et al.	1965	1.0-15	1273		The above specimen with additional 2 hr at 1673 K and density of 1.77 g cm^{-3}.
86	T35840	Schatz, E.A., et al.	1965	1.0-15	1273		The above specimen with additional 2 hr at 1923 K and density of 3.34 g cm^{-3}.

TABLE 6-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

λ	ϵ
CURVE 1	
T = 873.	
2.03	0.465
3.00	0.531
4.03	0.552
5.03	0.830
6.03	0.949
6.99	0.974
7.99	0.980
9.00	0.980
10.01	0.975
11.01	0.969
11.99	0.830
13.02	0.776
14.04	0.724
CURVE 2	
T = 1303.	
1.03	0.430
2.03	0.498
3.03	0.555
4.08	0.606
5.03	0.864
6.02	0.939
7.03	0.958
8.01	0.965
9.02	0.976
10.02	0.972
11.00	0.949
11.98	0.852
12.98	0.806
14.00	0.763
CURVE 3	
T = 873.	
1.99	0.393
3.00	0.442
4.00	0.477
5.00	0.729
CURVE 3 (CONT.)	
6.03	0.866
7.04	0.932
8.03	0.954
9.06	0.967
10.07	0.964
11.04	0.871
12.00	0.636
13.03	0.626
14.04	0.581
CURVE 4	
T = 1303.	
2.01	0.420
2.99	0.450
3.99	0.516
5.01	0.791
6.02	0.922
7.02	0.973
8.02	0.967
9.01	0.983
10.00	0.985
10.99	0.929
12.02	0.713
13.02	0.677
14.04	0.641
CURVE 5	
T = 873.	
1.99	0.367
2.97	0.450
3.97	0.484
5.00	0.726
6.01	0.844
6.98	0.904
7.98	0.922
8.99	0.933
9.99	0.942
10.98	0.845
CURVE 5 (CONT.)	
12.01	0.651
12.99	0.630
13.98	0.605
CURVE 6	
T = 1323.	
1.99	0.431
2.98	0.499
3.98	0.576
4.98	0.816
5.99	0.942
6.97	0.984
7.98	0.972
8.95	0.986
9.98	0.986
11.01	0.940
12.01	0.742
13.01	0.711
14.02	0.680
CURVE 7	
T = 560.	
4.21	0.283
4.55	0.643
4.75	0.081
4.79	0.463
4.84	0.256
5.01	0.505
5.05	0.618
5.24	0.505
5.38	0.536
5.54	0.400
5.61	0.597
5.91	0.670
6.43	0.608
6.56	0.592
7.21	0.584
7.59	0.567
CURVE 7 (CONT.)	
7.91	0.580
8.23	0.629
8.58	0.683
8.91	0.683
9.17	0.679
9.49	0.597
9.75	0.562
10.05	0.607
10.30	0.605
10.80	0.557
11.03	0.528
11.32	0.506
11.53	0.475
11.73	0.464
12.02	0.450
12.22	0.383
CURVE 8	
T = 560.	
4.20	0.105
4.54	0.558
4.76	0.264
5.04	0.468
5.05	0.589
5.37	0.764
5.61	0.597
5.88	0.607
6.40	0.577
6.85	0.556
7.19	0.532
7.58	0.515
7.90	0.484
8.26	0.569
8.57	0.621
8.87	0.644
9.17	0.610
9.45	0.546
9.74	0.471
10.02	0.593
CURVE 8 (CONT.)	
10.28	0.553
10.80	0.504
11.02	0.452
11.29	0.417
11.54	0.399
11.73	0.368
12.03	0.362
12.22	0.306
CURVE 9	
T = 1300.	
1.00	0.435
1.28	0.486
1.59	0.533
1.97	0.547
2.32	0.551
2.88	0.561
3.36	0.574
3.55	0.566
3.76	0.558
4.13	0.584
4.63	0.664
5.19	0.779
5.40	0.829
5.75	0.885
6.03	0.917
6.21	0.934
6.75	0.956
7.56	0.973
8.16	0.983
8.74	0.987
9.00	0.991
9.50	0.987
10.00	0.975
CURVE 10	
T = 1300.	
1.00	0.372
CURVE 10 (CONT.)	
1.30	0.421
1.61	0.444
1.93	0.456
2.45	0.455
2.96	0.456
3.48	0.464
3.90	0.478
4.12	0.509
4.38	0.570
4.83	0.635
5.46	0.628
5.81	0.835
6.17	0.924
6.31	0.936
6.75	0.956
7.56	0.973
8.16	0.983
8.74	0.987
9.00	0.991
9.50	0.987
10.00	0.975
CURVE 11	
T = 923.	
1.01	0.421
2.01	0.481
2.99	0.539
3.97	0.602
4.97	0.831
6.00	0.912
7.01	0.952
8.00	0.971
9.02	0.968
9.97	0.959
10.9	0.931
12.0	0.805
13.0	0.781
13.9	0.760
14.9	0.722

TABLE 6-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 12	
T = 814.	
1.	0.55
2.	0.27
3.	0.20
4.	0.31
5.	0.69
8.	0.98
11.	0.83
14.	0.57
CURVE 13	
T = 1055.	
1.	0.40
2.	0.21
3.	0.19
4.	0.35
5.	0.72
8.	0.98
11.	0.91
14.	0.60
CURVE 14	
T = 1227.	
1.	0.32
2.	0.19
3.	0.18
4.	0.37
5.	0.75
8.	0.97
11.	0.92
14.	0.68
CURVE 15	
T = 1410.	
1.	0.27
2.	0.19
3.	0.19
CURVE 15 (CONT.)	
4.	0.39
5.	0.77
8.	0.97
11.	0.94
14.	0.59
CURVE 16	
T = 1592.	
1.	0.31
2.	0.23
3.	0.21
4.	0.44
5.	0.79
8.	0.96
11.	0.94
14.	0.62
CURVE 17	
T = 813.	
1.	0.50
2.	0.30
3.	0.30
4.	0.34
5.	0.72
8.	0.98
11.	0.90
14.	0.59
CURVE 18	
T = 1053.	
1.	0.36
2.	0.30
3.	0.29
4.	0.38
5.	0.77
8.	0.96
11.	0.94
CURVE 18 (CONT.)	
14.	0.64
CURVE 19	
T = 1188.	
1.	0.29
2.	0.26
3.	0.17
4.	0.39
5.	0.78
8.	0.98
11.	0.94
14.	0.63
CURVE 20	
T = 1423.	
1.	0.22
2.	0.23
3.	0.27
4.	0.45
5.	0.79
8.	0.98
11.	0.96
14.	0.80
CURVE 21	
T = 1423.	
1.00	0.240
2.00	0.237
2.65	0.251
2.97	0.271
3.50	0.336
3.80	0.399
4.13	0.497
4.65	0.698
4.99	0.801
5.68	0.900
6.51	0.968
CURVE 21 (CONT.)	
7.00	0.983
8.00	1.000
9.03	1.000
10.0	0.996
11.0	0.948
11.6	0.799
12.0	0.739
12.9	0.691
13.7	0.640
14.0	0.631
14.5	0.639
15.0	0.662
CURVE 22	
T = 822.	
1.	0.60
2.	0.37
3.	0.40
4.	0.42
5.	0.72
8.	0.98
11.	0.74
14.	0.62
CURVE 23	
T = 1063.	
1.	0.63
2.	0.34
3.	0.38
4.	0.43
5.	0.74
8.	0.98
11.	0.92
14.	0.65
CURVE 24	
T = 1183.	
1.	0.41
2.	0.33
3.	0.34
4.	0.45
5.	0.69
8.	0.98
11.	0.95
14.	0.69
CURVE 25	
T = 1401.	
1.	0.29
2.	0.33
3.	0.33
4.	0.46
5.	0.81
8.	0.98
11.	0.95
14.	0.74
CURVE 26	
T = 1526.	
1.	0.48
2.	0.48
3.	0.44
4.	0.44
5.	0.80
6.	0.98
11.	0.93
14.	0.66
CURVE 27	
T = 813.	
1.	0.83
2.	0.39
3.	0.41
CURVE 27 (CONT.)	
4.	0.43
5.	0.76
8.	0.96
11.	0.91
14.	0.67
CURVE 28	
T = 1035.	
1.	0.46
2.	0.29
3.	0.40
4.	0.45
5.	0.75
8.	0.96
11.	0.93
14.	0.66
CURVE 29	
T = 1220.	
1.	0.39
2.	0.28
3.	0.38
4.	0.38
5.	0.76
8.	0.95
11.	0.92
14.	0.67
CURVE 30	
T = 1413.	
1.	0.32
2.	0.30
3.	0.37
4.	0.37
5.	0.77
8.	0.94
11.	0.93

TABLE 6-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 30 (CONT.)	
14.	0.72
CURVE 31 T = 1591.	
1.	0.34
2.	0.29
3.	0.34
4.	0.49
5.	0.79
8.	0.94
11.	0.93
14.	0.71
CURVE 32 T = 811.	
1.	0.74
2.	0.57
3.	0.52
4.	0.48
5.	0.76
8.	0.93
11.	0.98
14.	0.68
CURVE 33 T = 1053.	
1.	0.65
2.	0.52
3.	0.51
4.	0.51
5.	0.50
8.	0.98
11.	0.98
14.	0.73
CURVE 34 T = 1206.	
1.	0.47
2.	0.50
3.	0.59
4.	0.51
5.	0.81
8.	0.98
11.	0.98
14.	0.70
CURVE 35 T = 1413.	
1.	0.36
2.	0.47
3.	0.47
4.	0.52
5.	0.62
8.	0.97
11.	0.93
14.	0.72
CURVE 36 T = 1513.	
1.	0.32
2.	0.43
3.	0.44
4.	0.51
5.	0.81
8.	0.97
11.	0.93
14.	0.73
CURVE 37 T = 813.	
1.	0.65
2.	0.69
3.	0.60
CURVE 37 (CONT.)	
4.	0.48
5.	0.75
8.	1.00
11.	0.95
14.	0.58
CURVE 38 T = 1053.	
1.	0.57
2.	0.72
3.	0.59
4.	0.52
5.	0.77
8.	0.99
11.	0.95
14.	0.72
CURVE 39 T = 1188.	
1.	0.61
2.	0.70
3.	0.57
4.	0.52
5.	0.78
8.	1.00
11.	0.95
14.	0.71
CURVE 40 T = 1423.	
1.	0.69
2.	0.72
3.	0.56
4.	0.58
5.	0.79
8.	1.00
11.	0.96
CURVE 40 (CONT.)	
14.	0.88
CURVE 41 T = 822.	
1.	0.35
2.	0.35
3.	0.33
4.	0.32
5.	0.61
8.	1.00
11.	0.76
14.	0.62
CURVE 42 T = 1063.	
1.	0.54
2.	0.29
3.	0.29
4.	0.33
5.	0.60
8.	0.98
11.	0.83
14.	0.65
CURVE 43 T = 1183.	
1.	0.44
2.	0.29
3.	0.31
4.	0.34
5.	0.64
8.	0.98
11.	0.95
14.	0.67
CURVE 44 T = 1401.	
1.	0.34
2.	0.27
3.	0.31
4.	0.31
5.	0.65
8.	0.96
11.	0.95
14.	0.70
CURVE 45 T = 1523.	
1.	0.30
2.	0.25
3.	0.33
4.	0.32
5.	0.67
8.	0.98
11.	0.97
14.	0.68
CURVE 46 T = 833.	
1.	0.46
2.	0.13
3.	0.13
4.	0.34
5.	0.55
8.	0.98
11.	0.93
14.	0.64
CURVE 47 T = 1037.	
1.	0.43
2.	0.18
3.	0.18
CURVE 47 (CONT.)	
4.	0.28
5.	0.63
8.	0.96
11.	0.93
14.	0.62
CURVE 48 T = 1208.	
1.	0.35
2.	0.17
3.	0.18
4.	0.28
5.	0.71
8.	0.97
11.	0.94
14.	0.64
CURVE 49 T = 1395.	
1.	0.21
2.	0.13
3.	0.15
4.	0.29
5.	0.63
8.	0.85
11.	0.94
14.	0.59
CURVE 50 T = 1572.	
1.	0.12
2.	0.09
3.	0.052
4.	0.26
5.	0.63
8.	0.95
11.	0.96

TABLE 6-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

CURVE 50 (CONT.)

λ	ε
14.	0.57

CURVE 51
T = 814.

λ	ε
1.	0.30
2.	0.47
3.	0.48
4.	0.46
5.	0.76
8.	1.00
11.	0.95
14.	0.58

CURVE 52
T = 1053.

λ	ε
1.	0.50
2.	0.43
3.	0.46
4.	0.47
5.	0.77
8.	0.98
11.	0.84
14.	0.61

CURVE 53
T = 1125.

λ	ε
1.	0.46
2.	0.39
3.	0.40
4.	0.46
5.	0.76
8.	0.97
11.	0.92
14.	0.66

CURVE 54
T = 1408.

λ	ε
1.	0.34
2.	0.40
3.	0.40
4.	0.49
5.	0.78
8.	0.97
11.	0.93
14.	0.60

CURVE 55
T = 1592.

λ	ε
1.	0.30
2.	0.36
3.	0.39
4.	0.50
5.	0.80
8.	0.96
11.	0.91
14.	0.62

CURVE 56
T = 813.

λ	ε
1.	0.84
2.	0.96
3.	0.93
4.	0.90
5.	0.95
8.	0.98
11.	0.83
14.	0.42

CURVE 57
T = 1034.

λ	ε
1.	0.86
2.	0.90
3.	0.83

CURVE 57 (CONT.)

λ	ε
4.	0.90
5.	0.94
8.	0.95
11.	0.90
14.	0.49

CURVE 58
T = 1220.

λ	ε
1.	0.89
2.	0.86
3.	0.95
4.	0.86
5.	0.95
8.	0.95
11.	0.89
14.	0.45

CURVE 59
T = 1413.

λ	ε
1.	0.84
2.	0.85
3.	0.83
4.	0.83
5.	0.94
8.	0.94
11.	0.90
14.	0.46

CURVE 60
T = 1595.

λ	ε
1.	0.78
2.	0.81
3.	0.82
4.	0.90
5.	0.93
8.	0.95
11.	0.93

CURVE 60 (CONT.)

λ	ε
14.	0.54

CURVE 61
T = 1303.

λ	ε
0.92	0.424
2.04	0.497
2.96	0.556
3.99	0.611
5.01	0.859
6.06	0.931
7.07	0.941
8.17	0.960
9.07	0.991
10.0	0.988
11.0	0.941
12.0	0.850
13.1	0.492
14.0	0.750

CURVE 62
T = 1303.

λ	ε
0.92	0.446
2.99	0.503
4.03	0.581
5.03	0.811
6.08	0.939
7.03	0.981
8.13	0.969
9.10	0.979
10.0	0.981
11.0	0.929
12.0	0.759
13.1	0.711
14.0	0.679

CURVE 63
T = 1323.

λ	ε
2.07	0.420
2.96	0.447
3.97	0.504
4.99	0.763
6.09	0.930
7.08	0.972
8.13	0.964
9.13	0.981
10.1	0.983
11.0	0.912
12.0	0.720
13.1	0.667
14.0	0.633

CURVE 64
T = 1400.

λ	ε
2.	0.053
5.	0.410
8.	0.969
11.	0.964
14.	0.845

CURVE 65
T = 1400.

λ	ε
2.	0.066
5.	0.436
8.	0.976
11.	0.975
14.	0.861

CURVE 66
T = 1073.

λ	ε
1.00	0.251
1.24	0.234
1.55	0.224
1.96	0.217

CURVE 66 (CONT.)

λ	ε
2.32	0.223
2.52	0.231
2.66	0.251
2.73	0.397
2.78	0.421
2.83	0.431
2.92	0.422
3.01	0.391
3.18	0.353
3.31	0.336
3.61	0.384
3.81	0.436
4.01	0.491
4.13	0.545
4.21	0.602
4.34	0.595
4.46	0.652
4.60	0.732
4.86	0.822
5.19	0.888
5.48	0.927
6.00	0.959
6.66	0.932
7.21	0.932
7.57	0.934
8.02	0.988
8.27	0.976
8.51	0.954
8.86	0.969
9.38	0.988
9.76	0.994
10.3	0.994
10.7	0.977
11.0	0.953
11.3	0.907
11.6	0.837
12.1	0.791
12.3	0.789
13.4	0.822
14.0	0.825

TABLE 6-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE 66 (CONT.)		CURVE 68		CURVE 69 (CONT.)		CURVE 70 (CONT.)		CURVE 71 (CONT.)		CURVE 72 (CONT.)	
15.0	0.791	T = 1600.		4.0	0.169	7.5	0.945	7.15	0.936	11.4	0.674
CURVE 67		1.0	0.097	4.5	0.287	8.0	0.968	7.39	0.965	11.6	0.593
T = 1073.		1.5	0.088	5.0	0.431	8.5	0.939	7.69	0.981	11.7	0.575
1.00	0.245	2.0	0.085	5.5	0.572	9.0	0.965	8.02	0.990	12.5	0.579
1.57	0.221	2.5	0.089	6.0	0.695	9.5	0.978	8.55	0.993	12.8	0.605
1.98	0.212	3.0	0.097	6.5	0.821	10.0	0.984	8.93	0.978	13.7	0.587
2.45	0.213	3.5	0.125	7.0	0.910	10.5	0.982	9.39	0.976	14.0	0.570
2.66	0.240	4.0	0.177	7.5	0.956	11.0	0.958	9.86	0.980	14.6	0.561
2.86	0.394	4.5	0.316	8.0	0.975	11.5	0.885	10.1	0.979	15.0	0.551
3.39	0.341	5.0	0.459	8.5	0.947	12.0	0.836	10.5	0.966	CURVE 73	
3.77	0.414	5.5	0.595	9.0	0.973	12.5	0.833	10.8	0.941	T = 993.	
4.00	0.491	6.0	0.715	9.5	0.985	13.0	0.833	11.1	0.906	1.00	0.104
4.21	0.572	6.5	0.832	10.0	0.989	13.5	0.833	11.4	0.859	3.09	0.104
4.35	0.553	7.0	0.912	10.5	0.987	14.0	0.828	11.6	0.840	3.59	0.112
4.53	0.652	7.5	0.955	11.0	0.972	14.5	0.814	11.9	0.830	3.74	0.122
4.58	0.735	8.0	0.973	11.5	0.909	15.0	0.799	12.4	0.824	3.98	0.163
4.98	0.825	8.5	0.944	12.0	0.860	CURVE 71		13.3	0.823	4.13	0.206
5.42	0.910	9.0	0.957	12.5	0.848	T = 1255.		14.1	0.810	4.78	0.423
5.84	0.939	9.5	0.981	13.0	0.849	1.00	0.132	14.5	0.799	5.57	0.633
6.68	0.967	10.0	0.955	13.5	0.848	1.27	0.130	CURVE 72		5.95	0.708
7.44	0.976	10.5	0.986	14.0	0.841	2.04	0.094	T = 885.		6.59	0.796
7.99	0.985	11.0	0.971	14.5	0.830	2.55	0.091	1.00	0.104	6.83	0.816
8.49	0.942	11.5	0.921	15.0	0.813	2.95	0.087	3.09	0.104	7.08	0.832
9.38	0.971	12.0	0.673	CURVE 70		3.27	0.107	3.78	0.113	7.78	0.849
9.57	0.985	12.5	0.856	T = 1200.		3.85	0.183	3.93	0.134	8.79	0.862
10.0	0.986	13.0	0.852	1.0	0.060	4.28	0.326	4.11	0.166	9.19	0.875
10.4	0.982	13.5	0.852	1.5	0.046	4.40	0.361	4.92	0.425	10.4	0.882
10.6	0.963	14.0	0.846	2.0	0.042	4.59	0.380	5.26	0.521	10.6	0.875
11.3	0.914	14.5	0.833	2.5	0.045	5.11	0.401	6.16	0.722	10.8	0.849
12.1	0.834	15.0	0.813	3.0	0.058	5.41	0.423	6.35	0.753	11.0	0.799
12.6	0.770	CURVE 69		3.5	0.080	5.66	0.448	7.08	0.832	11.4	0.683
13.3	0.747	T = 1400.		4.0	0.141	5.87	0.481	7.78	0.849	11.6	0.639
14.2	0.700	1.0	0.073	4.5	0.248	6.13	0.531	8.79	0.862	11.8	0.613
15.0	0.675	1.5	0.063	5.0	0.389	6.28	0.573	9.19	0.875	12.5	0.616
		2.0	0.061	5.5	0.530	6.47	0.649	10.4	0.882	13.0	0.623
		2.5	0.065	6.0	0.653	6.53	0.715	10.6	0.868	13.5	0.608
		3.0	0.075	6.5	0.789	6.63	0.781	10.8	0.846	14.1	0.597
		3.5	0.106	7.0	0.892	6.85	0.870	11.0	0.805	14.7	0.571

TABLE 6-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

λ	ϵ
CURVE 73(CONT.)	
15.0	0.551
CURVE 74	
T = 1143.	
1.00	0.104
3.09	0.104
3.33	0.115
3.59	0.126
3.87	0.170
4.59	0.456
5.14	0.606
5.71	0.733
6.18	0.806
6.75	0.864
7.42	0.883
10.4	0.914
10.7	0.901
11.1	0.836
11.3	0.787
11.5	0.722
11.7	0.690
12.0	0.655
12.9	0.658
14.0	0.647
14.7	0.608
15.0	0.601
CURVE 75	
T = 1273.	
1.00	0.104
3.09	0.109
3.30	0.115
3.60	0.140
3.78	0.153
4.01	0.240
4.62	0.534
5.00	0.613
5.43	0.713

λ	ϵ
CURVE 75(CONT.)	
6.15	0.826
6.65	0.870
7.24	0.896
9.46	0.916
10.4	0.923
10.6	0.917
11.1	0.847
11.6	0.727
11.8	0.703
12.0	0.687
12.3	0.673
13.8	0.665
14.5	0.641
15.0	0.614
CURVE 76	
T = 373.	
1.00	0.183
3.35	0.174
4.04	0.169
4.26	0.216
4.91	0.384
5.21	0.456
5.51	0.568
5.79	0.671
6.15	0.773
6.41	0.820
6.63	0.857
7.00	0.872
7.67	0.894
10.3	0.906
10.6	0.867
10.8	0.821
11.4	0.566
11.5	0.520
11.6	0.504
12.3	0.596
12.6	0.606
13.4	0.600

λ	ϵ
CURVE 76(CONT.)	
14.2	0.528
15.0	0.440
CURVE 77	
T = 1273.	
1.00	0.100
2.99	0.102
3.29	0.113
3.51	0.146
3.75	0.196
4.02	0.282
4.32	0.460
4.67	0.595
5.08	0.724
5.48	0.806
6.17	0.898
6.52	0.925
7.30	0.953
9.52	0.953
10.4	0.965
11.0	0.952
11.2	0.900
11.4	0.817
11.5	0.781
11.8	0.752
12.3	0.719
13.3	0.705
13.7	0.686
14.3	0.641
15.0	0.590
CURVE 78	
T = 1273.	
1.0	0.100
3.01	0.101
3.33	0.111
3.63	0.145
3.92	0.208

λ	ϵ
CURVE 78(CONT.)	
4.08	0.273
4.45	0.466
4.72	0.577
5.19	0.694
5.75	0.790
6.38	0.866
6.91	0.903
7.54	0.924
10.1	0.946
10.5	0.938
10.9	0.914
11.0	0.896
11.5	0.773
12.0	0.696
12.3	0.669
13.4	0.662
13.9	0.641
14.7	0.595
15.0	0.561
CURVE 79	
T = 1273.	
1.00	0.100
3.01	0.101
3.33	0.111
3.63	0.145
3.92	0.203
4.08	0.273
4.45	0.466
4.72	0.577
5.19	0.694
5.75	0.790
6.38	0.866
6.91	0.903
7.54	0.924
10.1	0.946
10.5	0.938
10.9	0.914
11.0	0.896

λ	ϵ
CURVE 79(CONT.)	
11.5	0.773
12.0	0.696
12.3	0.669
13.4	0.662
13.9	0.641
14.7	0.595
15.0	0.561
CURVE 80	
T = 1273.	
1.00	0.100
3.30	0.100
3.54	0.114
3.89	0.174
4.24	0.309
4.65	0.498
5.13	0.631
5.56	0.741
6.35	0.826
7.01	0.880
7.65	0.896
10.2	0.904
10.7	0.896
11.0	0.866
11.7	0.701
11.9	0.666
12.3	0.639
13.2	0.629
13.8	0.614
14.5	0.569
15.0	0.539
CURVE 81	
T = 1273.	
1.00	0.085
1.99	0.089
2.51	0.096
3.02	0.102

λ	ϵ
CURVE 81(CONT.)	
3.26	0.112
3.52	0.128
3.67	0.137
3.80	0.150
3.90	0.168
4.01	0.198
4.23	0.304
4.78	0.536
5.15	0.665
5.44	0.755
5.70	0.813
5.95	0.877
6.17	0.910
6.45	0.944
6.71	0.959
6.90	0.976
7.17	1.000
8.05	0.989
9.07	0.975
9.58	0.969
10.25	0.959
10.63	0.951
11.22	0.936
11.71	0.926
12.01	0.911
12.23	0.895
12.62	0.888
13.46	0.884
13.83	0.893
14.43	0.893
14.65	0.886
15.00	0.885
CURVE 82	
T = 1273.	
1.00	0.085
1.99	0.089
2.96	0.089
3.27	0.090

TABLE 6-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 82(CONT.)	
3.50	0.099
3.64	0.110
3.80	0.125
3.93	0.155
4.07	0.187
4.24	0.239
4.47	0.323
4.72	0.423
4.94	0.502
5.22	0.601
5.52	0.694
5.80	0.751
6.05	0.825
6.25	0.860
6.53	0.902
6.75	0.924
7.01	0.944
7.40	0.959
7.71	0.963
9.13	0.963
9.50	0.957
9.99	0.947
10.60	0.948
11.22	0.936
11.71	0.926
12.01	0.911
12.28	0.898
12.62	0.888
13.46	0.884
13.83	0.893
14.43	0.893
14.65	0.886
15.00	0.885
CURVE 83	
T = 1273.	
1.00	0.085
1.99	0.089
2.96	0.089

λ	ε
CURVE 83(CONT.)	
3.27	0.090
3.50	0.099
3.64	0.110
3.80	0.125
3.93	0.155
4.07	0.187
4.23	0.277
4.45	0.331
4.77	0.449
4.83	0.478
4.94	0.519
5.04	0.566
5.33	0.656
5.53	0.698
5.80	0.763
6.05	0.819
6.24	0.860
6.41	0.873
6.64	0.897
6.81	0.913
7.05	0.930
7.33	0.942
8.41	0.942
8.75	0.935
9.99	0.936
10.60	0.931
11.20	0.926
11.52	0.908
11.89	0.898
12.62	0.885
13.46	0.884
13.83	0.893
14.43	0.893
14.65	0.885
15.00	0.885
CURVE 84	
T = 1273.	
1.00	0.085

λ	ε
CURVE 84(CONT.)	
1.99	0.089
2.96	0.089
3.27	0.090
3.50	0.099
3.64	0.110
3.80	0.125
3.93	0.143
4.06	0.168
4.19	0.201
4.38	0.258
4.59	0.322
4.97	0.447
5.24	0.537
5.52	0.620
5.76	0.697
5.94	0.731
6.25	0.792
6.40	0.816
6.60	0.848
6.83	0.872
7.04	0.885
7.33	0.897
8.58	0.897
9.27	0.900
10.60	0.900
10.77	0.900
11.10	0.885
11.53	0.879
12.04	0.863
12.58	0.856
13.71	0.856
14.47	0.851
15.00	0.839
CURVE 85	
T = 1273.	
1.00	0.085
1.99	0.089
2.96	0.089

λ	ε
CURVE 85(CONT.)	
3.27	0.090
3.50	0.099
3.64	0.110
3.80	0.125
3.93	0.143
4.06	0.168
4.19	0.201
4.38	0.258
4.64	0.351
4.90	0.444
5.17	0.532
5.44	0.623
5.76	0.712
5.90	0.753
6.10	0.795
6.33	0.831
6.60	0.864
6.85	0.890
7.07	0.911
7.38	0.926
7.89	0.926
8.63	0.921
10.04	0.921
10.40	0.931
10.60	0.931
11.08	0.928
11.33	0.911
11.86	0.878
11.97	0.866
12.59	0.855
13.56	0.842
14.59	0.842
15.00	0.836
CURVE 86	
T = 1273.	
1.00	0.085
1.99	0.089
2.96	0.089

λ	ε
CURVE 86(CONT.)	
3.27	0.090
3.50	0.099
3.64	0.110
3.80	0.125
3.93	0.155
4.07	0.187
4.22	0.237
4.34	0.299
4.54	0.371
4.78	0.450
5.06	0.541
5.24	0.585
5.47	0.633
5.71	0.673
5.87	0.700
6.14	0.743
6.39	0.770
6.66	0.799
7.05	0.817
7.66	0.826
8.54	0.837
9.75	0.837
10.21	0.845
10.60	0.845
10.72	0.837
10.91	0.822
11.04	0.804
11.53	0.692
11.62	0.642
12.03	0.612
12.50	0.613
13.14	0.622
13.74	0.622
14.00	0.603
14.48	0.562
14.62	0.543
14.81	0.516
15.00	0.489

b. Normal Spectral Emittance (Temperature Dependence)

A total of seven sets of experimental data were located for the temperature dependence of the normal spectral emittance of aluminum oxide as listed in Table 6-6 and shown in Figure 6-8. Specimen characterization and measurement information for the data are given in Table 6-5. All the data are for wavelengths of 1 μm or below.

However, provisional values at 3.8 and 10.6 μm for Coors AD 99 are shown in Figure 6-7 and are listed in Table 6-4. The values were obtained from the two provisional curves in the previous section. The uncertainty in each point is 15%. The lines connecting the two points for each wavelength are not to imply a smooth curve and are used merely as an aid in visualizing and integrating the values presented.

TABLE 6-4. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (COORS AD 99) (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ	T	ϵ
λ = 3.8		λ = 10.6	
1303.	0.543	1303.	0.966
1423.	0.399	1423.	0.966

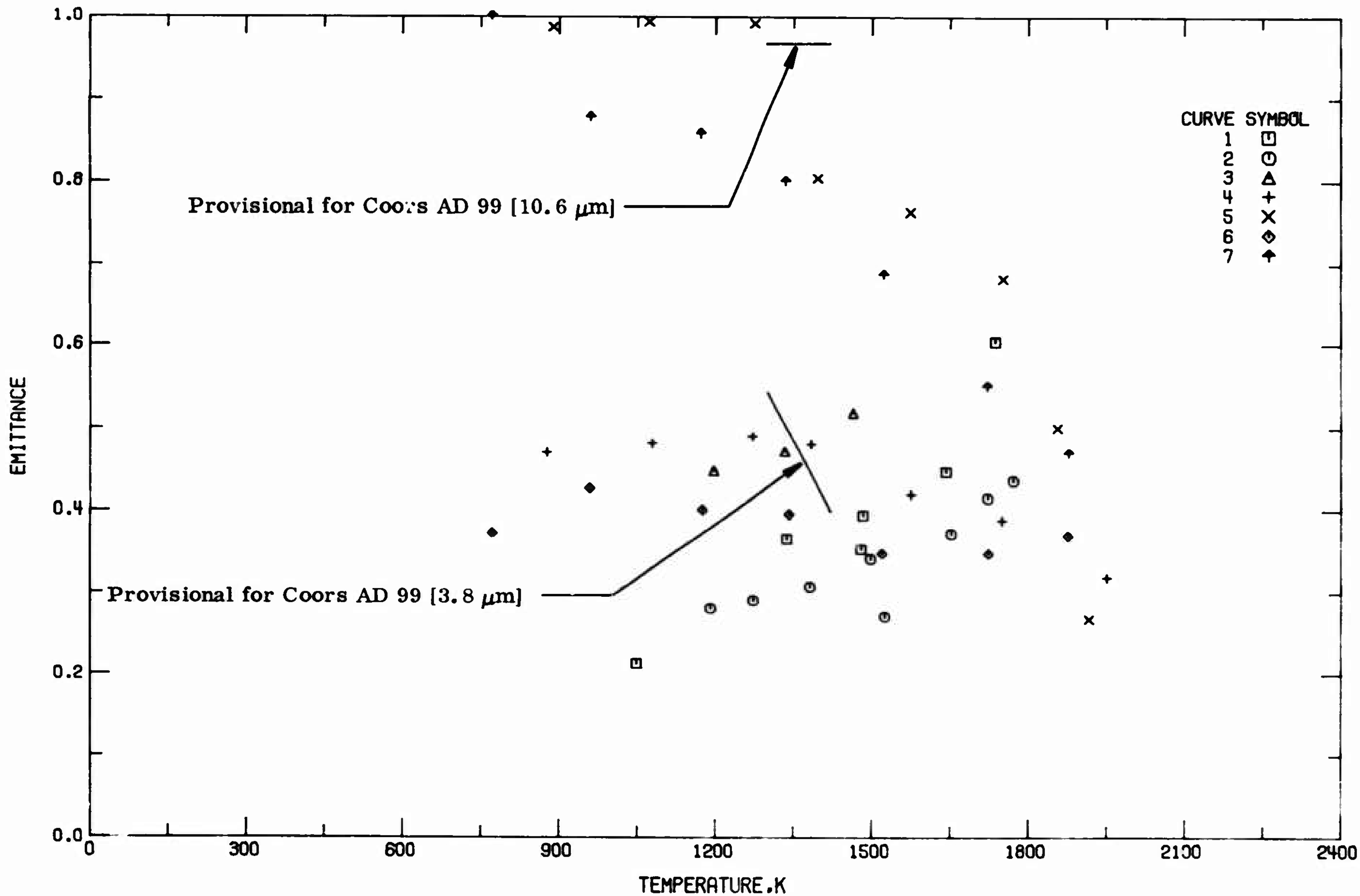


FIGURE 6-7. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (TEMPERATURE DEPENDENCE).

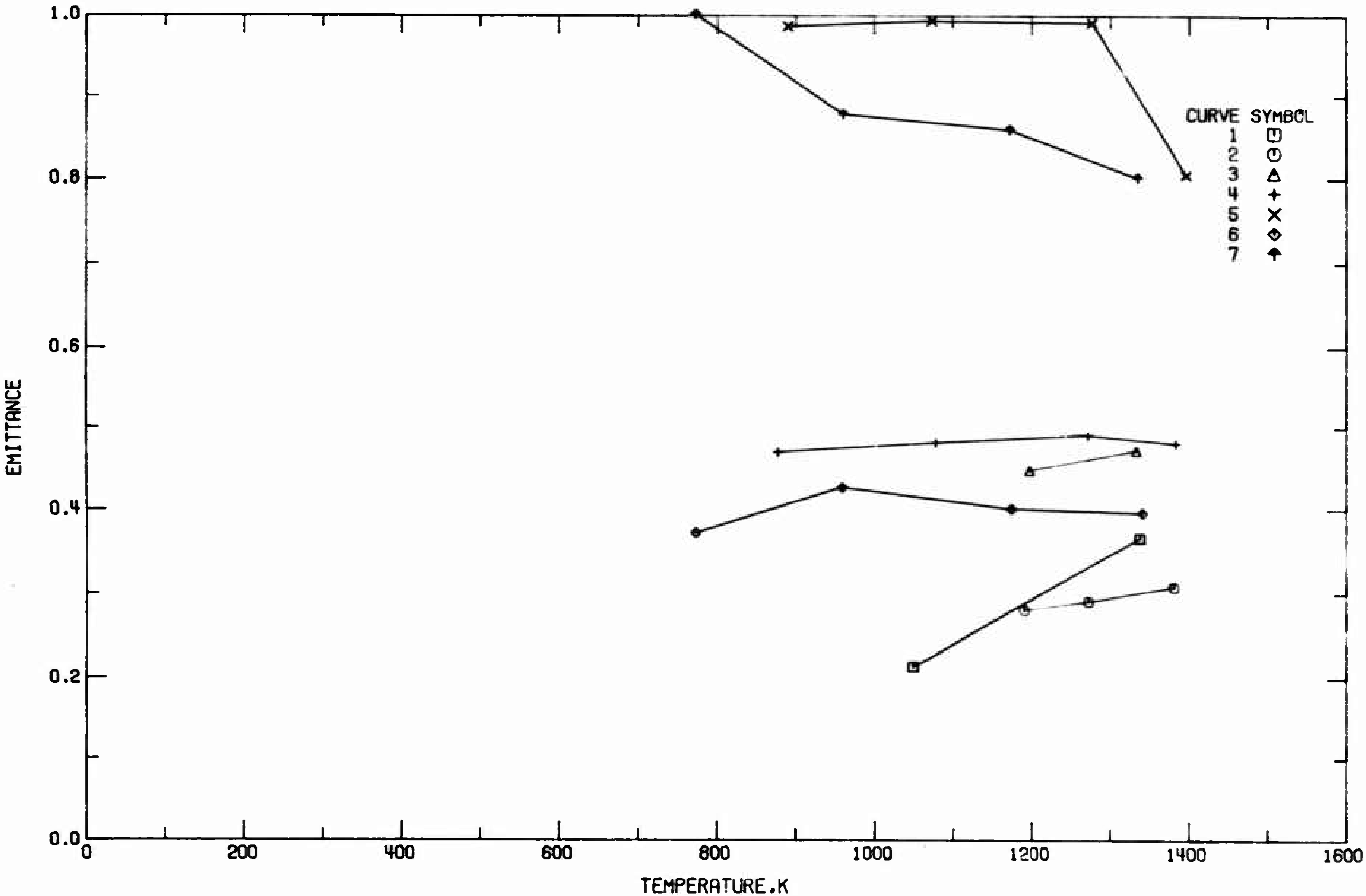


FIGURE 6-8. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (TEMPERATURE DEPENDENCE).

TABLE 6-5. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T10060	Olson, O.H. and Morris, J.C.	1959	0.665	1050-1740	Norton LA603	Data from figure; $\theta' = 0°$.
2	T10060	Olson, O.H. and Morris, J.C.	1959	0.665	1191-1773	Norton RA4213	Data from figure; $\theta' = 0°$.
3	T10060	Olson, O.H. and Morris, J.C.	1959	0.665	1198-1465	Norton Rokide A	Material on stainless steel No. 446; data from figure; $\theta' = 0°$.
4	T18630	Blair, G.R.	1960	0.640	878-1953	Frenchtown alumina 4402	Ground to size, ultrasonically cleaned, surface polished with 1-5 μm diamond polishing compound until normally mat surface began to reflect light; cleaned, polished with cloth charged with a paste of cerium oxide and kerosene; measured in vacuum; data from figure; emissivity reported; $\theta' = 0°$; reported error ~10%.
5	T18630	Blair, G.R.	1960	1	891-1919	Frenchtown alumina 4402	The above specimen.
6	T18630	Blair, G.R.	1960	0.640	773-1878	Coors alumina AD 99	Similar to the above specimen.
7	T18630	Blair, G.R.	1960	1	773-1880	Coors alumina AD 99	The above specimen.

TABLE 6-6. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM OXIDE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ
CURVE 1 λ = 0.665	
1050.	0.213
1339.	0.366
1482.	0.353
1485.	0.394
1645.	0.445
1740.	0.603
CURVE 2 λ = 0.665	
1191.	0.280
1273.	0.290
1382.	0.337
1499.	0.341
1526.	0.270
1654.	0.372
1724.	0.414
1773.	0.434
CURVE 3 λ = 0.665	
1198.	0.446
1334.	0.470
1469.	0.519
CURVE 4 λ = 0.640	
878.	0.463
1079.	0.430
1272.	0.439
1354.	0.479
1579.	0.418
1751.	0.388
1953.	0.319

T	ϵ
CURVE 5 λ = 1.0	
891.	0.985
1075.	0.992
1278.	0.990
1397.	0.803
1576.	0.762
1754.	0.681
1858.	0.500
1919.	0.267
CURVE 6 λ = 0.640	
773.	0.372
960.	0.425
1175.	0.400
1342.	0.395
1521.	0.347
1726.	0.347
1878.	0.370
CURVE 7 λ = 1.0	
773.	1.000
962.	0.876
1173.	0.657
1335.	0.800
1524.	0.687
1724.	0.550
1880.	0.468

c. Normal Spectral Reflectance (Wavelength Dependence)

A total of 31 sets of experimental data were located for the wavelength dependence of the normal spectral reflectance of aluminum oxide as listed in Table 6-8 and shown in Figure 6-9. Figure 6-9 does not show the data for curves 4, 9-13, and 30-31. The data for these curves reported in the literature are relative values and some individual data points are over 1.0. The computer program handling the plotting divides any data over 1.0 by 100. and hence the curves having such data were not plotted. Specimen characterization and measurement information for the data are given in Table 6-7.

The data are predominately for wavelengths below 2.7 μm. The data above 2.7 μm are not identified with any specific brand names nor are there confirmatory data for these data sets. For these reasons, taken together, it is not thought justified to pursue developing evaluated data.

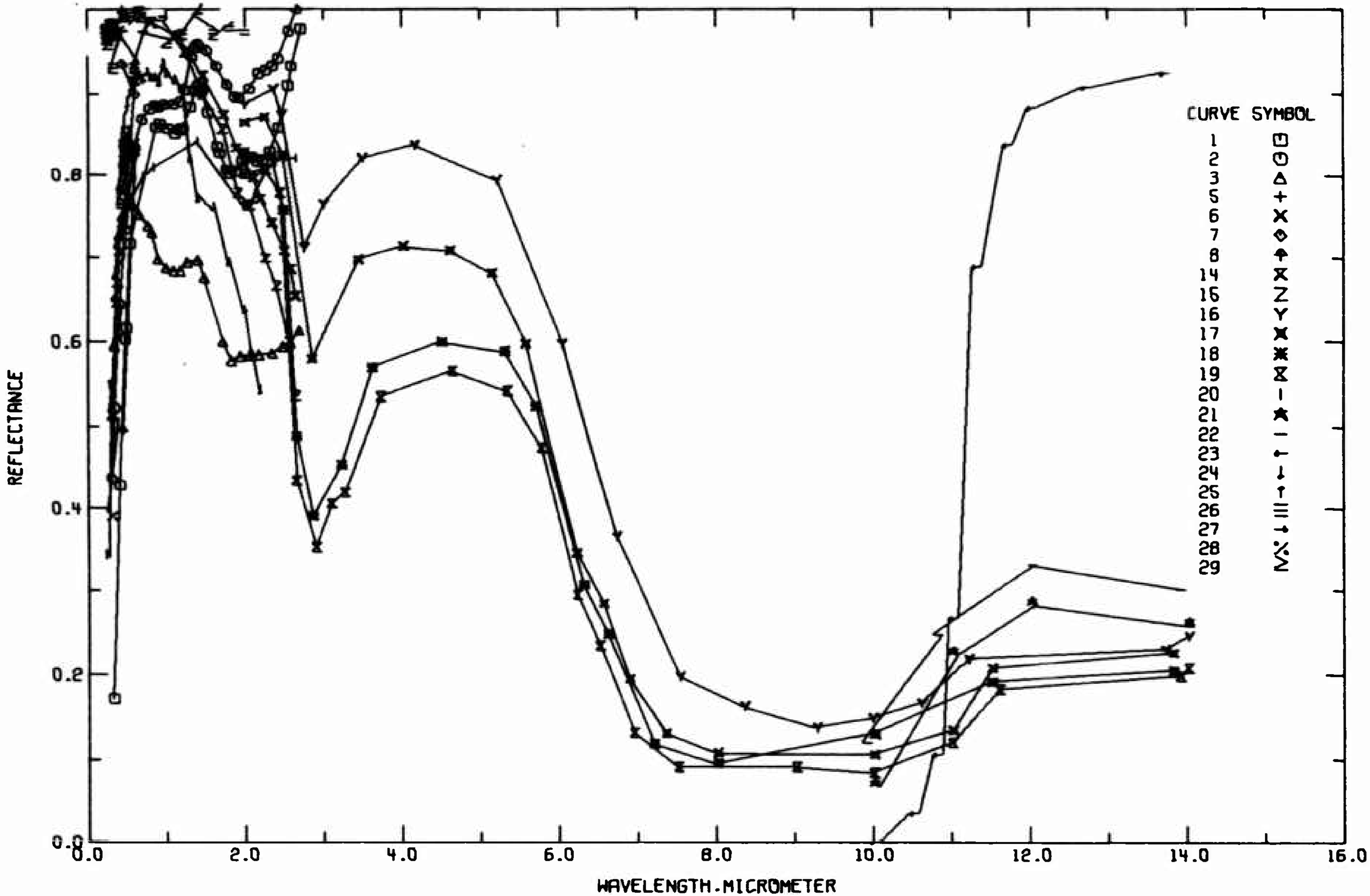


FIGURE 6-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE).

TABLE 6-7. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF ALUMINUM OXIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T10060	Olson, O.H. and Morris, J.C.	1959	0.30-2.7	293	Norton LA603	Working standard magnesium carbonate surface; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; integrating sphere reflectometer used, reflectance factor measured then values converted to absolute reflectance values; $\theta = 9°$, $\omega' = 2\pi$; reported error 4%.
2	T10060	Olson, O.H. and Morris, J.C.	1959	0.30-2.7	293	Norton RA4213	Similar to the above specimen.
3	T10060	Olson, O.H. and Morris, J.C.	1959	0.31-2.7	293	Norton Rokide A	Similar to the above specimen except material on stainless steel No. 446.
4	T22272	Schatz, E.A., Goldberg, D.M., Pearson, E.G., and Burks, T.L.	1963	0.23-2.7	293	Sample No. 112	Sintered at 1923 K for 1 hr, setter material Al_2O_3; thickness 69 mils; density 3.45 g cm^{-3}, theoretical density 3.97 g cm^{-3}; MgO reference standard, reflectance data measured and presented relative to MgO; spectral total reflectance reported; integrating sphere reflectometer, Beckman DK-2a spectroreflectometer used; measurement temperature not given explicitly, 293 K assigned; smooth values from figure; $\theta = 5°$, $\omega' = 2\pi$.
5	T28755	Zerlaut, G.A. and Harada, Y.	1963	0.44,0.60	293	Alucer MC, alpha	Supplied by Gulton Industries; powder compacted at 10 000 psi; MgO used as standard, absolute values of reflectance reported; integrating sphere reflectometer used; measurement temperature not given explicitly, assumed to be 293 K; $\theta \sim 0°$, $\omega' = 2\pi$.
6	T28755	Zerlaut, G.A. and Harada, Y.	1963	0.44,0.60	293	Alucer MC, alpha	The above specimen except exposed to uv irradiation; 180 ESH with solar factor 3.
7	T28755	Zerlaut, G.A. and Harada, Y.	1963	0.44,0.60	293	Alucer MA, gamma	Supplied by Gulton Industries; powder compacted at 10 000 psi; MgO used as standard, absolute values of reflectance reported; integrating sphere reflectometer used; measurement temperature not given explicitly, assumed to be 293 K; $\theta \sim 0°$, $\omega' = 2\pi$.
8	T28755	Zerlaut, G.A. and Harada, Y.	1963	0.44,0.60	293	Alucer MA, gamma	The above specimen except exposed to uv irradiation; 75 ESH with solar factor 1.5.
9	T34908	Schatz, E.A.	1966	0.23-2.7	293		> 99 pure; compacted powder; compaction pressure 290 psi; MgO reference standard; spectral total reflectance versus MgO presented; Beckman DK-2A spectroreflectometer used; measurement temperature not given explicitly, assumed to be 293 K; smooth values from figure; $\theta \sim 0°$, $\omega' = 2\pi$.
10	T34908	Schatz, E.A.	1966	0.23-2.7	293		Similar to the above specimen except compacted at 1150 psi.
11	T34908	Schatz, E.A.	1966	0.23-2.7	293		Similar to the above specimen except compacted at 2880 psi.
12	T34908	Schatz, E.A.	1966	0.23-2.7	293		Similar to the above specimen except compacted at 5760 psi.
13	T34908	Schatz, E.A.	1966	0.23-2.7	293		Similar to the above specimen except compacted at 11 500 psi.
14	T34908	Schatz, E.A.	1966	0.23-2.7	293		Similar to the above specimen except compacted at 20 200 psi
15	T34908	Schatz, E.A.	1966	0.23-2.7	293		Similar to the above specimen except compacted at 28 800 psi.
16	T34908	Schatz, E.A.	1966	2.0-15	293		>99 pure; compacted powder; compaction pressure 700 psi; absolute spectral total reflectance reported; blackbody reflectometer used in conjunction with Baird-Atomic model NK-1 spectrophotometer; smooth values from figure; $\theta \sim 0°$, $\omega' = 2\pi$.
17	T34908	Schatz, E.A.	1966	2.0-15	293		Similar to the above specimen except compacted at 7000 psi.
18	T34908	Schatz, E.A.	1966	2.0-15	293		Similar to the above specimen except compacted at 28 000 psi.
19	T34908	Schatz, E.A.	1966	2.0-15	293		Similar to the above specimen except compacted at 42 000 psi.

TABLE 6-7. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF ALUMINUM OXIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
20	T40230	Schatz, E.A.	1967	0.23-2.7	293		Powder; commercially pure; -230 to +270 mesh, pressed at 24,300 Newtons cm^{-2}; 1.6 mm thick and 22 mm in diameter stainless steel; Beckman DK-2A spectroreflectometer used; curves presented relative to smoked MgO standard; measurement temperature not explicitly given, assumed to be 293 K; smooth values from figure; $\theta \sim 0^\circ$, $\omega' = 2\pi$.
21	T40528	Sulzbach, F. and Turner, A.F.	1966	10.0-36.0	293		Clear film; electron beam deposited at normal incidence on glass at 423 K at 2 to 8×10^{-5} mm Hg; rate of deposit 1 quarterwave min^{-1} at $\lambda = 0.5$ μm; optical film thickness, index of refraction times thickness equals 10 $\lambda/4$ at 2.3 μm; measurement temperature specified as room temperature, 293 K assigned; Perkin Elmer model 21 and 221 spectrophotometers used for reflectance measurements; $\theta \sim 0^\circ$.
22	T40528	Sulzbach, F. and Turner, A.F.	1966	9.9-37	293		Similar to the above specimen except electron beam deposited at normal incidence on glass at 588 K; index of refraction times thickness equals 10 $\lambda/4$ at 2.2 μm.
23	T40528	Sulzbach, F. and Turner, A.F.	1966	10-37	293		Crystal; polished; smooth values from figure; measurement temperature specified as room temperature, 293 K assigned; Perkin Elmer models 21 and 221 spectrophotometers used for reflectance measurements; $\theta \sim 0^\circ$.
24	T45667	De La Perrelle, E.T., and Herbert, H.	1962	0.4-2.2	293	Specimen X64	Integrating sphere reflectometer used with magnesium carbonate as inside liner of sphere; absolute reflectance factor ($\omega = 2\pi$; $\theta' = 0^\circ$) actually measured, equated to reflectance ($\theta = 0^\circ$; $\omega' = 2\pi$), angles θ and θ' presumed to be approx. 0°; measurement temperature not given explicitly, assumed to be 293 K.
25	T45700	Wilcock, D.F. and Soller, W.	1940	0.28-0.32	293		Dry pigment; packed in shallow steel cell; integrating sphere with magnesium oxide coating on inside used to measure absolute reflectance factor; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 0^\circ$, $\omega' = 2\pi$.
26	T49037	Zerlaut, G.A., Tompkins, E.H., Harada, Y., and Marshall, G.C.	1964	0.32-2.0	293	Sample 34	Pressed compact; Cary spectrophotometer used; presume $\theta = 0^\circ$, $\omega' = 2\pi$; measurement temperature not given explicitly, assumed to be 293 K.
27	T34814	Strindehag, O.M.	1966	0.43-0.54	293	Reflector VIII	Sintered; A123 and A124 supplied by Degussa; relative reflectance factor ($\omega = 2\pi$; $\theta' = 0^\circ$), compared to smoked MgO reference standard, actually measured, equated to reflectance factor ($\theta = 0^\circ$; $\omega' = 2\pi$); Zeiss Elrepho photometer used in reflectance measurement, diffuse illumination of specimen with white light and observation direction perpendicular to specimen; measurement temperature not explicitly given, 293 K assigned.
28	T34814	Strindehag, O.M.	1966	0.31-0.59	293	Reflector VIII	The above specimen except PMQII spectrometer used with RA3 reflection attachment; RA3 used monochromatic light directed perpendicular to the specimen and integrating measurement of total diffuse reflection made.
29	T34814	Strindehag, O.M.	1966	0.43-0.54	293	Reflector VIII	The above specimen except exposed to 423 K deionized water for 10 days and Elrepho photometer used for measurement.
30	T35840	Schatz, E.A., Alvarez, C.H., Counts, C.R., III, and Hoppke, M.A.	1965	0.23-2.7	293		Sintered 15 hr at 1273 K; density 1.58; MgO reference standard; Beckman DK-2A spectroreflectometer used; smooth values from figure; measurement temperature not explicitly given, assumed to be 293 K; $\theta = 5^\circ$, $\omega' = 2\pi$.
31	T35840	Schatz, E.A., et al.	1965	0.23-2.7	293		The above specimen except sintered an additional 2 hr at 1923 K; density changed to 3.34.

TABLE 6-8. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 293.	
0.304	0.171
0.389	0.429
0.462	0.603
0.473	0.616
0.519	0.717
0.849	0.859
0.900	0.863
0.959	0.857
1.09	0.851
1.16	0.855
1.19	0.858
1.29	0.864
1.35	0.904
1.39	0.909
1.43	0.904
1.51	0.877
1.63	0.834
1.66	0.827
1.75	0.806
1.79	0.801
1.87	0.805
1.95	0.817
2.07	0.822
2.14	0.817
2.21	0.819
2.30	0.829
2.41	0.859
2.53	0.910
2.57	0.933
2.69	0.977
CURVE 2	
T = 293.	
0.301	0.437
0.334	0.524
0.398	0.645
0.472	0.733
0.533	0.736

λ	ρ
CURVE 2(CONT.)	
0.588	0.834
0.678	0.868
0.779	0.881
0.852	0.886
0.887	0.884
0.970	0.887
1.08	0.887
1.17	0.890
1.22	0.905
1.31	0.944
1.36	0.955
1.40	0.959
1.50	0.952
1.63	0.933
1.77	0.911
1.87	0.896
1.93	0.895
2.06	0.906
2.17	0.924
2.26	0.928
2.35	0.933
2.42	0.942
2.55	0.974
2.65	1.000
CURVE 3	
T = 293.	
0.307	0.513
0.332	0.595
0.395	0.727
0.439	0.750
0.525	0.767
0.565	0.763
0.647	0.752
0.766	0.738
0.809	0.730
0.892	0.698
0.995	0.687
1.091	0.684

λ	ρ
CURVE 3(CONT.)	
1.177	0.684
1.263	0.694
1.398	0.697
1.481	0.676
1.718	0.600
1.829	0.578
1.945	0.583
2.075	0.584
2.188	0.585
2.356	0.566
2.492	0.594
2.585	0.599
2.702	0.613
CURVE 4	
T = 293.	
0.231	0.260
0.241	0.259
0.250	0.242
0.258	0.238
0.266	0.246
0.274	0.285
0.280	0.333
0.285	0.375
0.290	0.435
0.300	0.517
0.310	0.573
0.320	0.608
0.330	0.634
0.340	0.662
0.350	0.678
0.450	0.805
0.503	0.844
0.561	0.867
0.651	0.895
0.800	0.917
0.815	0.914
0.890	0.913
0.912	0.923

λ	ρ
CURVE 4(CONT.)	
1.04	0.928
1.15	0.934
1.24	0.940
1.39	0.952
1.55	0.956
1.75	0.968
1.84	0.976
1.95	0.976
2.15	0.995
2.24	1.00
2.44	1.01
2.55	1.26
2.65	1.05
CURVE 5	
T = 293.	
0.440	1.000
0.600	1.000
CURVE 6	
T = 293.	
0.440	0.740
0.600	0.915
CURVE 7	
T = 293.	
0.440	0.935
0.600	0.900
CURVE 8	
T = 293.	
0.440	0.495
0.600	0.825

λ	ρ
CURVE 9	
T = 293.	
0.230	1.000
0.243	1.000
0.270	1.012
0.280	1.021
0.289	1.033
0.318	1.020
0.347	1.020
0.350	1.022
0.571	1.031
0.849	1.030
1.01	1.038
1.15	1.034
1.47	1.036
1.69	1.047
1.90	1.038
2.26	1.047
2.43	1.042
2.51	1.044
2.65	1.029
CURVE 10	
T = 293.	
0.230	0.995
0.249	0.996
0.260	1.000
0.281	1.017
0.295	1.023
0.319	1.010
0.344	1.011
0.350	1.013
0.459	1.020
0.654	1.028
0.763	1.021
0.978	1.023
1.24	1.027
1.44	1.019
1.55	1.025
1.72	1.025

λ	ρ
CURVE 10(CONT.)	
1.88	1.014
2.07	1.020
2.20	1.011
2.30	1.012
2.45	1.000
2.65	0.972
CURVE 11	
T = 293.	
0.230	0.994
0.243	0.995
0.254	0.999
0.262	0.997
0.280	1.015
0.293	1.019
0.311	1.006
0.331	1.000
0.356	1.001
0.459	1.013
0.810	1.015
1.15	1.013
1.41	1.001
1.72	0.999
1.90	0.972
2.12	0.966
2.33	0.937
2.55	0.900
2.65	0.854
CURVE 12	
T = 293.	
0.230	0.984
0.239	0.990
0.252	0.983
0.260	0.994
0.270	0.989
0.288	1.002
0.310	0.991

TABLE 6-8. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 12(CONT.)	
0.344	0.990
0.350	0.995
0.421	1.001
0.500	1.001
0.641	1.006
0.956	1.006
1.26	1.001
1.43	0.989
1.69	0.981
1.87	0.955
2.03	0.949
2.36	0.913
2.56	0.869
2.65	0.837
CURVE 13	
T = 293.	
0.230	0.980
0.259	0.968
0.284	0.988
0.298	0.981
0.330	0.977
0.343	0.981
0.350	0.985
0.461	0.995
0.662	1.003
0.782	1.000
0.839	0.992
1.00	0.990
1.29	0.968
1.54	0.938
1.77	0.901
1.92	0.865
2.07	0.846
2.46	0.749
2.55	0.740
2.65	0.680
CURVE 14	
T = 293.	
0.230	0.977
0.246	0.964
0.256	0.967
0.284	0.983
0.305	0.978
0.330	0.974
0.350	0.981
0.442	0.992
0.652	0.997
0.800	0.985
1.15	0.969
1.46	0.921
1.73	0.874
1.89	0.833
2.11	0.796
2.20	0.770
2.35	0.741
2.51	0.708
2.59	0.686
2.65	0.654
CURVE 15	
T = 293.	
0.230	0.973
0.253	0.959
0.291	0.982
0.331	0.973
0.350	0.931
0.453	0.991
0.563	0.986
0.679	0.991
0.958	0.987
1.23	0.950
1.46	0.900
1.71	0.857
1.91	0.778
2.06	0.763
2.26	0.700
CURVE 15(CONT.)	
2.40	0.667
2.57	0.600
2.65	0.537
CURVE 16	
T = 293.	
2.00	0.887
2.36	0.906
2.47	0.874
2.76	0.712
3.01	0.764
3.50	0.821
4.17	0.837
5.21	0.794
6.04	0.598
6.73	0.365
7.53	0.198
8.35	0.162
9.27	0.137
9.98	0.148
10.6	0.166
11.2	0.219
13.7	0.230
14.0	0.246
15.0	0.246
CURVE 17	
T = 293.	
2.00	0.865
2.25	0.872
2.48	0.826
2.36	0.580
3.45	0.698
4.02	0.714
4.62	0.709
5.15	0.682
5.58	0.598
6.02	0.345
CURVE 17(CONT.)	
6.56	0.285
6.89	0.195
7.35	0.131
8.01	0.108
10.0	0.106
11.0	0.134
11.5	0.208
13.8	0.226
14.1	0.235
15.0	0.235
CURVE 18	
T = 293.	
2.00	0.828
2.34	0.822
2.49	0.757
2.66	0.489
2.87	0.390
3.23	0.454
3.63	0.570
4.51	0.600
5.31	0.589
5.71	0.525
6.31	0.387
6.62	0.249
7.20	0.119
8.01	0.096
10.0	0.130
11.5	0.191
13.8	0.205
14.1	0.221
15.0	0.219
CURVE 19	
T = 293.	
2.00	0.801
2.26	0.807
2.45	0.778
CURVE 19(CONT.)	
2.66	0.435
2.91	0.352
3.11	0.406
3.28	0.420
3.74	0.536
4.65	0.566
5.35	0.543
5.78	0.475
6.23	0.295
6.52	0.235
6.95	0.132
7.51	0.092
9.01	0.092
10.0	0.085
11.0	0.120
11.6	0.182
13.0	0.198
14.0	0.208
15.0	0.206
CURVE 20	
T = 293.	
0.230	0.342
0.259	0.344
0.266	0.354
0.274	0.406
0.285	0.459
0.294	0.500
0.316	0.569
0.335	0.613
0.346	0.643
0.350	0.684
0.373	0.711
0.456	0.741
0.560	0.770
0.708	0.797
0.838	0.809
1.39	0.841
1.99	0.762
CURVE 20(CONT.)	
2.07	0.762
2.14	0.777
2.30	0.809
2.39	0.816
2.51	0.823
2.65	0.821
CURVE 21	
T = 293.	
10.0	0.073
11.0	0.229
12.0	0.288
14.0	0.263
15.1	0.250
16.0	0.238
17.1	0.228
18.0	0.219
20.0	0.212
21.0	0.216
22.1	0.209
23.1	0.207
23.9	0.210
25.1	0.210
26.1	0.215
27.0	0.221
29.0	0.234
31.0	0.252
32.9	0.270
33.9	0.263
35.0	0.244
36.0	0.216
CURVE 22	
T = 293.	
9.9	0.119
10.8	0.248
12.0	0.331
13.9	0.301

TABLE 6-8. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

CURVE 22 (CONT.)

λ	ρ
14.7	0.287
15.0	0.307
18.0	0.239
19.9	0.268
21.9	0.245
23.9	0.238
25.9	0.247
27.9	0.272
30.5	0.313
32.5	0.305
33.1	0.352
33.9	0.288
35.9	0.233
36.9	0.275

CURVE 23
T = 293.

λ	ρ
10.0	0.000
10.5	0.036
10.8	0.106
11.0	0.267
11.3	0.689
11.7	0.837
12.0	0.883
12.7	0.907
13.7	0.924
14.6	0.926
15.1	0.913
15.4	0.338
15.8	0.836
16.2	0.856
19.2	0.164
19.5	0.129
19.7	0.685
20.0	0.698
20.4	0.680
20.8	0.512
20.9	0.899
21.3	0.955

CURVE 23 (CONT.)

λ	ρ
21.9	0.935
23.0	0.854
23.9	0.757
25.6	0.556
25.9	0.547
26.3	0.591
27.2	0.522
27.9	0.489
28.5	0.483
29.8	0.427
30.5	0.431
30.9	0.426
31.6	0.408
32.3	0.406
32.8	0.415
33.1	0.456
33.4	0.413
34.0	0.407
35.8	0.402
37.0	0.388

CURVE 24
T = 293.

λ	ρ
0.4	0.78
0.42	0.846
0.45	0.863
0.5	0.889
0.55	0.908
0.55	0.904
0.6	0.930
0.65	0.923
0.7	0.918
0.75	0.927
0.8	0.92
0.85	0.92
0.9	0.914
0.95	0.937
1.0	0.925
1.1	0.917

CURVE 24 (CONT.)

λ	ρ
1.2	0.906
1.3	0.82
1.4	0.771
1.6	0.761
1.8	0.695
2.0	0.639
2.1	0.585
2.2	0.544

CURVE 25
T = 293.

λ	ρ
0.28	0.55
0.32	0.55

CURVE 26
T = 293.

λ	ρ
0.325	0.93
0.375	0.97
0.450	0.98
0.600	0.93
0.700	0.98
1.0	0.96
1.2	0.97
1.4	1.00
1.6	0.97
1.8	0.98
2.0	0.97

CURVE 27
T = 293.

λ	ρ
0.4260	0.779
0.4570	0.835
0.4950	0.659
0.5400	0.832

CURVE 28
T = 293.

λ	ρ
0.3058	0.391
0.3265	0.514
0.3589	0.646
0.3721	0.671
0.3957	0.708
0.4525	0.789
0.4984	0.829
0.5381	0.822
0.5644	0.828
0.5916	0.840

CURVE 29
T = 293.

λ	ρ
0.4260	0.762
0.4570	0.813
0.4950	0.844
0.5400	0.832

CURVE 30
T = 293.

λ	ρ
0.231	0.073
0.235	0.084
0.237	0.104
0.244	0.280
0.246	0.310
0.252	0.335
0.275	0.381
0.315	0.446
0.328	0.472
0.343	0.513
0.347	0.538
0.350	0.562
0.361	0.630
0.371	0.669
0.380	0.729
0.388	0.752
0.407	0.836

CURVE 30 (CONT.)

λ	ρ
0.427	0.869
0.504	0.911
0.565	0.932
0.654	0.943
0.777	0.962
0.866	0.990
1.16	1.03
1.29	1.05
1.40	1.04
1.60	1.05
1.75	1.07
1.95	1.03
2.06	1.06
2.15	1.08
2.25	1.08
2.65	1.00

CURVE 31
T = 293.

λ	ρ
0.230	0.165
0.243	0.160
0.247	0.151
0.253	0.146
0.262	0.150
0.268	0.165
0.274	0.188
0.281	0.249
0.301	0.542
0.307	0.599
0.315	0.641
0.326	0.684
0.342	0.743
0.347	0.769
0.361	0.811
0.464	0.921
0.497	0.934
0.550	0.927
0.584	0.937
0.751	0.973

CURVE 31 (CONT.)

λ	ρ
0.863	0.981
0.928	0.979
1.52	1.03
1.80	1.06
1.96	1.07
2.07	1.09
2.17	1.09
2.36	1.11
2.65	1.11

d. Angular Spectral Reflectance (Wavelength Dependence)

A total of 10 sets of experimental data were located for the wavelength dependence of the angular spectral reflectance of aluminum oxide. These data are listed in Table 6-10 and shown in Figure 6-10. Specimen characterization and measurement information for the data are given in Table 6-9.

The data are all for a temperature of 293 K and none of the sets are for Coors alumina or other commercial alumina and, therefore, no data evaluation is possible.

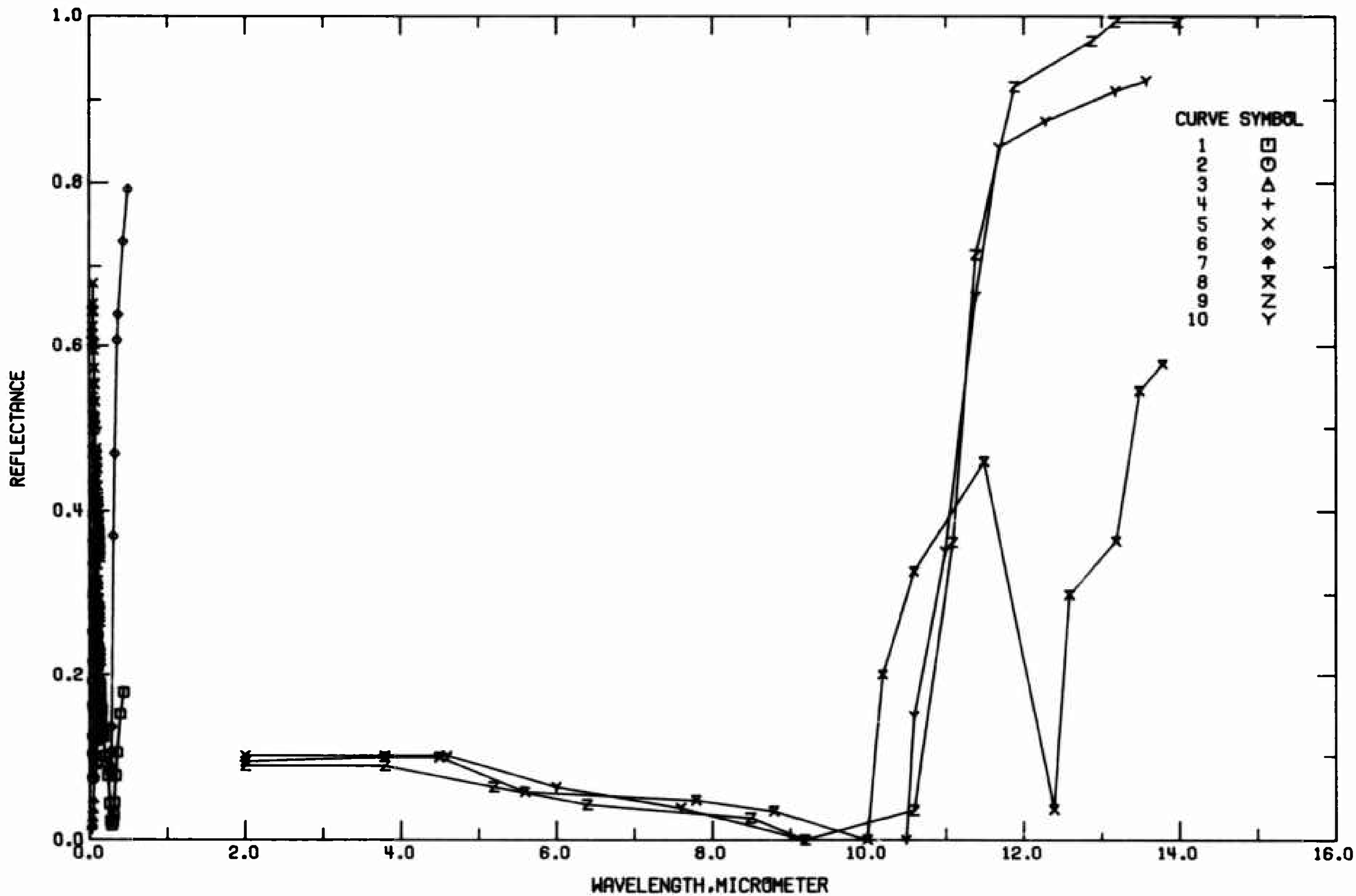


FIGURE 6-10. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE).

TABLE 6-9. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM OXIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T32363	Hass, G. and Tousey, R.	1959	0.058-0.44	293		Al_2O_3 film on SiO coated glass; both films were effectively λ/4 thick at 3000 Å; angles θ and θ' determined by measurement from diagram of evaporator (see Fig. 1 in T32363); measurement temperature not given explicitly, assumed to be 293 K; $\theta \sim 18°$, $\theta' \sim 18°$.
2	T48912	Arakawa, E.T. and Williams, M.W.	1968	0.0473-0.16	293	Corundum	Single crystal; cut with the optic axis parallel to the reflecting surface; polished using 6 μm diamond paste, followed by a final polish using 0.5 μm diamond paste on a Buehler microcloth wheel; measurement temperature not given explicitly, assumed to be 293 K; $\theta \sim 20°$, $\theta' \sim 20°$; reported error 2%.
3	T48912	Arakawa, E.T. and Williams, M.W.	1968	0.043-0.14	293	Corundum	The above specimen; $\theta = 50°$, $\theta' = 50°$.
4	T48912	Arakawa, E.T. and Williams, M.W.	1968	0.043-0.14	293	Corundum	The above specimen; $\theta = 60°$, $\theta' = 60°$.
5	T48912	Arakawa, E.T. and Williams, M.W.	1968	0.043-0.14	293	Corundum	The above specimen; $\theta = 70°$, $\theta' = 70°$.
6	T34614	Strindehag, O.M.	1966	0.26-0.50	293	Reflector No. VIII	Sintered A123 and A124 aluminum oxide; supplied by Degussa; relative reflectance factor determined; data reported relative to smoked MgO reference standard; PMQ II spectrometer used with RA2 reflection attachment; smooth values from figure; measurement temperature not explicitly given, 293 K assigned; $\theta = 45°$, $\theta' = 0°$.
7	T42891	Stephan, G., Lemonnier, J.C., and Robins, S.	1967	0.029-0.15	293	Corundum	Specimen cut perpendicular to the optic axis; measured in vacuum; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 20°$, $\theta' = 20°$.
8	T30100	McCarthy, D.E.	1963	2-50	293	Sapphire	Synthetic; specimen 2 mm thick, ground and polished to a flatness of seven fringes or better; reference standard was aluminum mirror; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; Beckman IR-5A used in 2-16 μm range and Beckman IR-7 with CsI interchange used in 12.5-50 μm range; $\theta = 30°$, $\theta' = 30°$.
9	T36324	McCarthy, D.E.	1965	2-50	293	Ruby	0.05 Cr, essentially sapphire with the chromium impurity; synthetic; specimen 6.10 mm thick; flat to 10 fringes or better; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 30°$, $\theta' = \theta'$.
10	T36324	McCarthy, D.E.	1965	2-50	293	Sapphire	Synthetic; specimen 3.0 mm thick; flat to 10 fringes or better; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 30°$, $\theta' = 30°$.

TABLE 6-18. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 293.	
0.0579	0.163
0.0731	0.181
0.0907	0.151
0.100	0.151
0.109	0.151
0.116	0.153
0.126	0.155
0.136	0.158
0.147	0.153
0.160	0.157
0.181	0.123
0.193	0.099
0.219	0.091
0.239	0.076
0.260	0.043
0.280	0.022
0.290	0.017
0.300	0.022
0.308	0.030
0.315	0.044
0.339	0.076
0.359	0.104
0.399	0.151
0.440	0.178
CURVE 2	
T = 293.	
0.0433	0.073
0.0450	0.102
0.0465	0.123
0.0480	0.162
0.0506	0.191
0.0525	0.216
0.0536	0.253
0.0576	0.302
0.0596	0.283
0.0607	0.251
0.0632	0.293
CURVE 2(CONT.)	
0.0642	0.288
0.0656	0.274
0.0692	0.267
0.0700	0.246
0.0712	0.250
0.0742	0.232
0.0765	0.217
0.0784	0.213
0.0826	0.218
0.0849	0.218
0.0892	0.244
0.0911	0.247
0.0946	0.248
0.0976	0.236
0.100	0.231
0.104	0.225
0.105	0.220
0.107	0.209
0.110	0.196
0.113	0.193
0.115	0.190
0.116	0.192
0.118	0.183
0.120	0.175
0.122	0.175
0.122	0.185
0.124	0.176
0.127	0.179
0.127	0.181
0.130	0.180
0.131	0.185
0.133	0.192
0.136	0.187
0.137	0.180
0.139	0.174
0.140	0.158
0.142	0.151
0.144	0.145
0.147	0.142
0.149	0.137
CURVE 2(CONT.)	
0.149	0.131
0.153	0.131
0.156	0.127
0.158	0.123
CURVE 3	
T = 293.	
0.0433	0.301
0.0452	0.341
0.0471	0.368
0.0482	0.403
0.0508	0.398
0.0527	0.428
0.0539	0.439
0.0574	0.442
0.0596	0.423
0.0607	0.359
0.0632	0.412
0.0642	0.396
0.0670	0.377
0.0688	0.355
0.0700	0.342
0.0712	0.338
0.0742	0.322
0.0770	0.291
0.0789	0.276
0.0821	0.291
0.0855	0.287
0.0892	0.311
0.0918	0.320
0.0946	0.316
0.0976	0.296
0.100	0.291
0.104	0.286
0.105	0.272
0.107	0.267
0.111	0.256
0.113	0.252
0.115	0.240
CURVE 3(CONT.)	
0.118	0.243
0.120	0.238
0.120	0.230
0.122	0.233
0.126	0.225
0.129	0.233
0.131	0.237
0.134	0.236
0.135	0.230
0.137	0.224
0.139	0.217
CURVE 4	
T = 293.	
0.0433	0.464
0.0454	0.477
0.0471	0.492
0.0482	0.518
0.0506	0.562
0.0527	0.531
0.0539	0.540
0.0576	0.534
0.0596	0.511
0.0607	0.441
0.0632	0.493
0.0645	0.469
0.0666	0.452
0.0688	0.430
0.0700	0.406
0.0712	0.406
0.0742	0.388
0.0770	0.365
0.0784	0.336
0.0832	0.357
0.0849	0.351
0.0898	0.368
0.0918	0.370
0.0953	0.366
0.0976	0.345
CURVE 4(CONT.)	
0.100	0.339
0.104	0.330
0.106	0.321
0.107	0.312
0.110	0.307
0.113	0.299
0.116	0.297
0.119	0.288
0.120	0.284
0.122	0.284
0.122	0.288
0.124	0.273
0.126	0.275
0.126	0.277
0.127	0.283
0.130	0.288
0.131	0.284
0.134	0.281
0.136	0.275
0.137	0.270
0.139	0.266
0.139	0.260
CURVE 5	
T = 293.	
0.0433	0.605
0.0454	0.613
0.0471	0.623
0.0482	0.641
0.0508	0.642
0.0527	0.652
0.0539	0.678
0.0572	0.642
0.0596	0.601
0.0607	0.552
0.0635	0.602
0.0642	0.593
0.0666	0.571
0.0688	0.551
CURVE 5(CONT.)	
0.0700	0.530
0.0708	0.511
0.0742	0.501
0.0770	0.471
0.0784	0.447
0.0826	0.467
0.0849	0.467
0.0898	0.475
0.0911	0.466
0.0946	0.458
0.0976	0.451
0.100	0.430
0.105	0.416
0.105	0.410
0.107	0.402
0.110	0.401
0.112	0.393
0.116	0.363
0.118	0.378
0.119	0.387
0.120	0.376
0.121	0.363
0.124	0.372
0.124	0.365
0.125	0.376
0.126	0.363
0.129	0.369
0.131	0.372
0.131	0.362
0.133	0.363
0.134	0.354
0.137	0.348
0.139	0.343
CURVE 6	
T = 293.	
0.2578	0.079
0.2674	0.087
0.2768	0.105

TABLE 6-13. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ
CURVE 6 (CONT.)	
0.2825	0.135
0.3063	0.369
0.3255	0.468
0.3605	0.606
0.3732	0.638
0.4365	0.729
0.4956	0.791
CURVE 7	
T = 293.	
0.0268	0.012
0.0336	0.015
0.0395	0.022
0.0443	0.032
0.0474	0.044
0.0522	0.073
0.0555	0.087
0.0597	0.094
0.0640	0.097
0.0658	0.094
0.0713	0.085
0.0738	0.085
0.0786	0.094
0.0867	0.113
0.0896	0.116
0.0941	0.115
0.0985	0.120
0.109	0.134
0.116	0.146
0.128	0.172
0.131	0.175
0.153	0.127
CURVE 8	
T = 293.	
2.0	0.093
3.8	0.098
4.5	0.098
CURVE 8 (CONT.)	
5.6	0.057
7.9	0.047
8.8	0.034
10.0	0.000
10.2	0.200
10.6	0.327
11.5	0.459
12.4	0.036
12.6	0.299
13.2	0.363
13.5	0.543
13.8	0.576
14.3	0.517
15.3	0.428
16.0	0.405
16.6	0.442
17.2	0.518
17.7	0.552
18.0	0.571
18.7	0.571
20.0	0.503
21.0	0.451
22.2	0.400
23.5	0.364
25.1	0.320
26.6	0.300
28.7	0.274
31.0	0.259
33.6	0.234
35.0	0.227
36.6	0.209
41.4	0.223
45.0	0.226
46.6	0.244
47.8	0.265
48.8	0.308
50.0	0.339
CURVE 9	
T = 293.	
2.0	0.088
3.8	0.088
5.2	0.063
6.4	0.042
8.5	0.026
9.2	0.000
10.6	0.035
11.1	0.362
11.4	0.713
11.9	0.914
12.9	0.968
13.2	0.991
14.0	0.991
15.1	0.944
15.5	0.900
15.6	0.894
16.2	0.804
16.7	0.705
17.4	0.663
17.6	0.494
18.2	0.405
19.3	0.258
19.9	0.347
20.1	0.265
20.5	0.227
20.8	0.564
21.0	0.790
21.5	0.876
22.3	0.771
22.6	0.616
23.9	0.461
25.7	0.414
26.4	0.502
27.4	0.441
28.6	0.399
30.0	0.362
34.0	0.364
38.5	0.364
40.9	0.351
CURVE 9 (CONT.)	
43.6	0.306
45.7	0.284
46.7	0.257
47.5	0.234
50.0	0.244
CURVE 10	
T = 293.	
2.0	0.100
3.8	0.100
4.6	0.100
6.0	0.063
7.6	0.038
9.2	0.000
10.5	0.000
10.6	0.149
11.0	0.351
11.4	0.662
11.7	0.841
12.3	0.873
13.2	0.909
13.6	0.921
14.5	0.930
15.5	0.809
16.0	0.825
16.8	0.690
17.7	0.543
18.5	0.410
19.0	0.303
19.5	0.375
19.9	0.485
20.4	0.430
20.8	0.781
21.2	0.853
21.6	0.882
22.1	0.859
22.6	0.798
23.0	0.727
23.8	0.657
CURVE 10 (CONT.)	
24.2	0.584
25.4	0.520
26.4	0.547
27.1	0.464
27.5	0.439
28.6	0.423
29.9	0.375
32.7	0.379
34.3	0.363
36.8	0.369
41.4	0.369
45.4	0.352
50.0	0.340

e. Normal Spectral Absorptance (Wavelength Dependence)

A total of five sets of experimental data were located for the wavelength dependence of the normal spectral absorptance of aluminum oxide. This data is listed in Table 6-12 and shown in Figure 6-11. Specimen characterization and measurement information for the data are given in Table 6-11.

The data are all for wavelengths below 1 μm and, hence, no data evaluation is justified.

Since $\alpha = \epsilon$ by Kirchhoff's law (Eq. 2.3-7), the provisional values for normal spectral emittance of Coors AD 99 also apply to the normal spectral absorptance. See Table 6-1 for a listing of these provisional values and Figures 6-1, 6-2, and 6-3 for a graphical presentation.

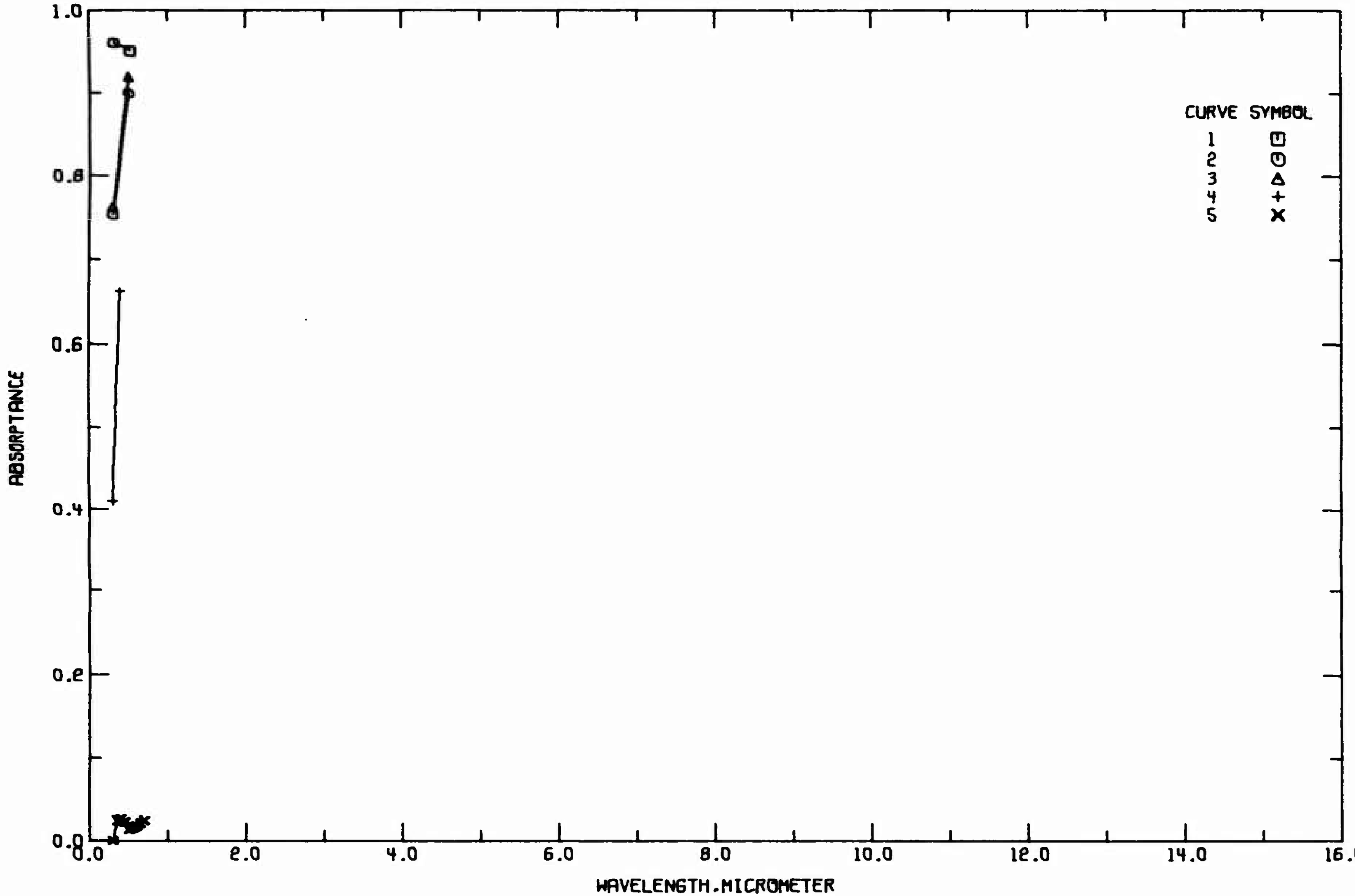


FIGURE 6-11. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE).

TABLE 6-11. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM OXIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T40412	Schutt, J.B. and Macklin, B.A.	1964	0.3-0.5	293		High purity γ-Al_2O_3; measured in vacuum; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 0^\circ$.
2	T40412	Schutt, J.B. and Macklin, B.A.	1964	0.3-0.5	293		The above specimen except subjected to 50 solar actinic hr using Hanovia 673A high pressure mercury lamp in a vacion system.
3	T40412	Schutt, J.B. and Macklin, B.A.	1964	0.3-0.5	293		High purity γ-Al_2O_3; slurried with 0.02 mole % H_2SO_4, dried, pressed into a pellet; measured in vacuum; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 0^\circ$.
4	T40412	Schutt, J.B. and Macklin, B.A.	1964	0.3-0.4	293		The above specimen except subjected to 50 solar actinic hr using Hanovia 673A high pressure mercury lamp in a vacion system.
5	T40563	Dubs, C.W.	1966	0.30-0.70	293	Alucer MC	Compacted powder; data from figure; measurement temperature not given explicitly, assumed to be 293 K; $\theta \sim 0^\circ$.

TABLE 6-12. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α
CURVE 1	
T = 293.	
0.3	0.96
0.5	0.95
CURVE 2	
T = 293.	
0.3	0.75
0.5	0.90
CURVE 3	
T = 293.	
0.3	0.76
0.5	0.92
CURVE 4	
T = 293.	
0.3	0.41
0.4	0.66
CURVE 5	
T = 293.	
0.300	0.000
0.351	0.024
0.400	0.027
0.450	0.022
0.500	0.013
0.550	0.015
0.600	0.017
0.650	0.020
0.700	0.024

f. Normal Spectral Absorptance (Temperature Dependence)

No experimental data was found for the temperature dependence of the normal spectral absorptance of aluminum oxide.

By Kirchhoff's law (Eq. 2.3-7) the provisional values for the temperature dependence of the normal spectral emittance are equal to the values for the temperature dependence of the normal spectral absorptance. See Table 6-4 for the listing of the provisional values and Figure 6-7 for a visual presentation.

g. Hemispherical Spectral Transmittance (Wavelength Dependence)

A total of 16 sets of experimental data were located for the wavelength dependence of the hemispherical spectral transmittance of aluminum oxide. These data are listed in Table 6-14 and shown in Figure 6-12. Specimen characterization and measurement information for the data are given in Table 6-13.

The data are all at room temperature and cover a wavelength range of 1 to 8 μm. The data are widely spaced, having come from tabular form, and drawing a smooth curve through the points for data evaluation is not justified. Lines are drawn between the data points in Figure 6-12 to aid in visualizing the data and do not imply a smooth curve connecting the data points.

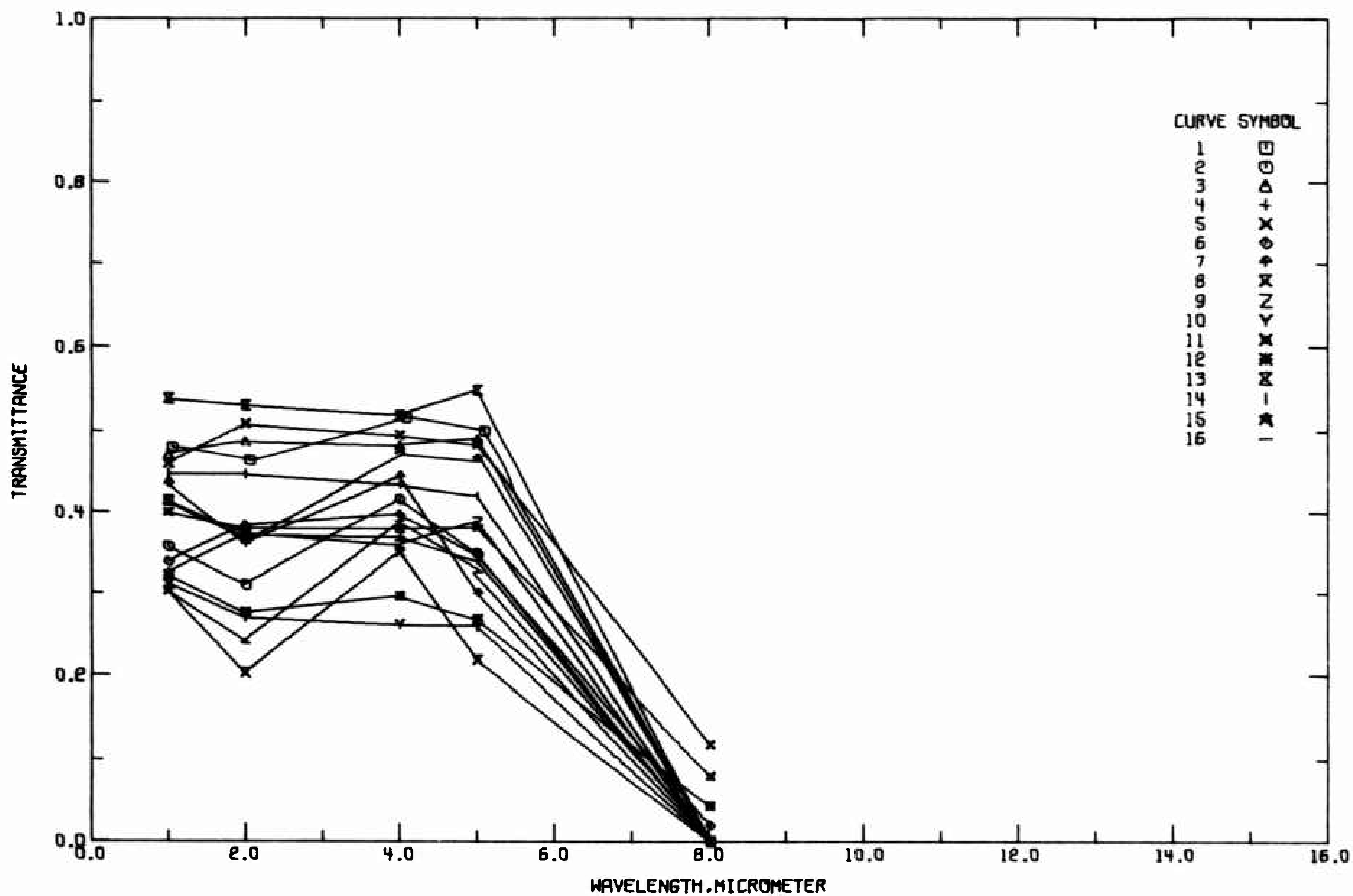


FIGURE 6-12. EXPERIMENTAL HEMISPHERICAL SPECTRAL TRANSMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE).

TABLE 6-13. MEASUREMENT INFORMATION ON THE HEMISPHERICAL SPECTRAL TRANSMITTANCE OF ALUMINUM OXIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, µm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T29570	Folweiler, R.C.	1964	1-8	293	McDanel AV30 alumina	96 pure; vitrified alumina; specimen 0.25 by 0.62 in. in cross section and 0.127 mm thick; measurement temperature not given explicitly, assumed to be 293 K; diffusing screen used in front of specimen; $\omega = 2\pi$, $\theta' \sim 0°$; reported error $\pm 5\%$.
2	T29570	Folweiler, R.C.	1964	1-8	293	McDanel AV30 alumina	Similar to the above specimen except 0.254 mm thick.
3	T29570	Folweiler, R.C.	1964	1-8	293	McDanel AP35 alumina, No. 3	Similar to the above specimen except 99 pure and 0.127 mm thick.
4	T29570	Folweiler, R.C.	1964	1-8	293	McDanel AP35 alumina, No. 3	Similar to the above specimen except 0.254 mm thick.
5	T29570	Folweiler, R.C.	1964	1-8	293	McDanel AP35 alumina, No. 4	Similar to the above specimen except 0.127 mm thick.
6	T29570	Folweiler, R.C.	1964	1-8	293	McDanel AP35 alumina, No. 4	Similar to the above specimen except 0.254 mm thick.
7	T29570	Folweiler, R.C.	1964	1-8	293	Coors AD-85 alumina	Similar to the above specimen except 85 pure and 0.127 mm thick.
8	T29570	Folweiler, R.C.	1964	1-8	293	Coors AD-85 alumina	Similar to the above specimen except 0.254 mm thick.
9	T29570	Folweiler, R.C.	1964	1-8	293	Coors AD-94 alumina	Similar to the above specimen except 94 pure and 0.127 mm thick.
10	T29570	Folweiler, R.C.	1964	1-8	293	Coors AD-94 alumina	Similar to the above specimen except 0.254 mm thick.
11	T29570	Folweiler, R.C.	1964	1-8	293	Coors AD-96 alumina	Similar to the above specimen except 96 pure and 0.127 mm thick.
12	T29570	Folweiler, R.C.	1964	1-8	293	Coors AD-96 alumina	Similar to the above specimen except 0.254 mm thick.
13	T29570	Folweiler, R.C.	1964	1-8	293	Coors AD-99 alumina	Similar to the above specimen except 99 pure and 0.127 mm thick.
14	T29570	Folweiler, R.C.	1964	1-8	293	Coors AD-99 alumina	Similar to the above specimen except 0.254 mm thick.
15	T29570	Folweiler, R.C.	1964	1-8	293	Coors AD-96 alumina	Similar to the above specimen except 1 $CoCO_3$ and 0.005 in. thick.
16	T29570	Folweiler, R.C.	1964	1-8	293	Coors AD-96 alumina	Similar to the above specimen except 0.010 in. thick.

TABLE 6-14. EXPERIMENTAL HEMISPHERICAL SPECTRAL TRANSMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 1 T = 293.	
1.	0.480
2.	0.463
4.	0.517
5.	0.531
8.	0.000
CURVE 2 T = 293.	
1.	0.357
2.	0.310
4.	0.416
5.	0.348
8.	0.000
CURVE 3 T = 293.	
1.	0.470
2.	0.487
4.	0.462
5.	0.490
8.	0.000
CURVE 4 T = 293.	
1.	0.325
2.	0.371
4.	0.369
5.	0.339
8.	0.000
CURVE 5 T = 293.	
1.	0.458
2.	0.539
4.	0.495
CURVE 5 (CONT.)	
5.	0.483
8.	0.119
CURVE 6 T = 293.	
1.	0.338
2.	0.383
4.	0.397
5.	0.346
8.	0.023
CURVE 7 T = 293.	
1.	0.435
2.	0.362
4.	0.443
5.	0.300
8.	0.000
CURVE 8 T = 293.	
1.	0.303
2.	0.202
4.	0.350
5.	0.218
8.	0.000
CURVE 9 T = 293.	
1.	0.414
2.	0.373
4.	0.358
5.	0.338
8.	0.000
CURVE 10 T = 293.	
1.	0.312
2.	0.270
4.	0.261
5.	0.259
8.	0.000
CURVE 11 T = 293.	
1.	0.400
2.	0.380
4.	0.378
5.	0.380
8.	0.080
CURVE 12 T = 293.	
1.	0.322
2.	0.276
4.	0.296
5.	0.268
8.	0.043
CURVE 13 T = 293.	
1.	0.539
2.	0.531
4.	0.519
5.	0.548
8.	0.000
CURVE 14 T = 293.	
1.	0.446
2.	0.445
4.	0.433
CURVE 14 (CONT.)	
5.	0.420
8.	0.000
CURVE 15 T = 293.	
1.	0.415
2.	0.370
4.	0.476
5.	0.466
8.	0.000
CURVE 16 T = 293.	
1.	0.306
2.	0.237
4.	0.390
5.	0.326
8.	0.000

h. Normal Spectral Transmittance (Wavelength Dependence)

A total of 18 sets of experimental data were located for the wavelength dependence of the normal spectral transmittance of aluminum oxide. These data are listed in Table 6-16 and shown in Figure 6-13. Specimen characterization and measurement information for the data are given in Table 6-15.

Because the data that are potentially useful are widely spaced, no evaluated data can be given. The lines connecting such data points do not imply a smooth curve.

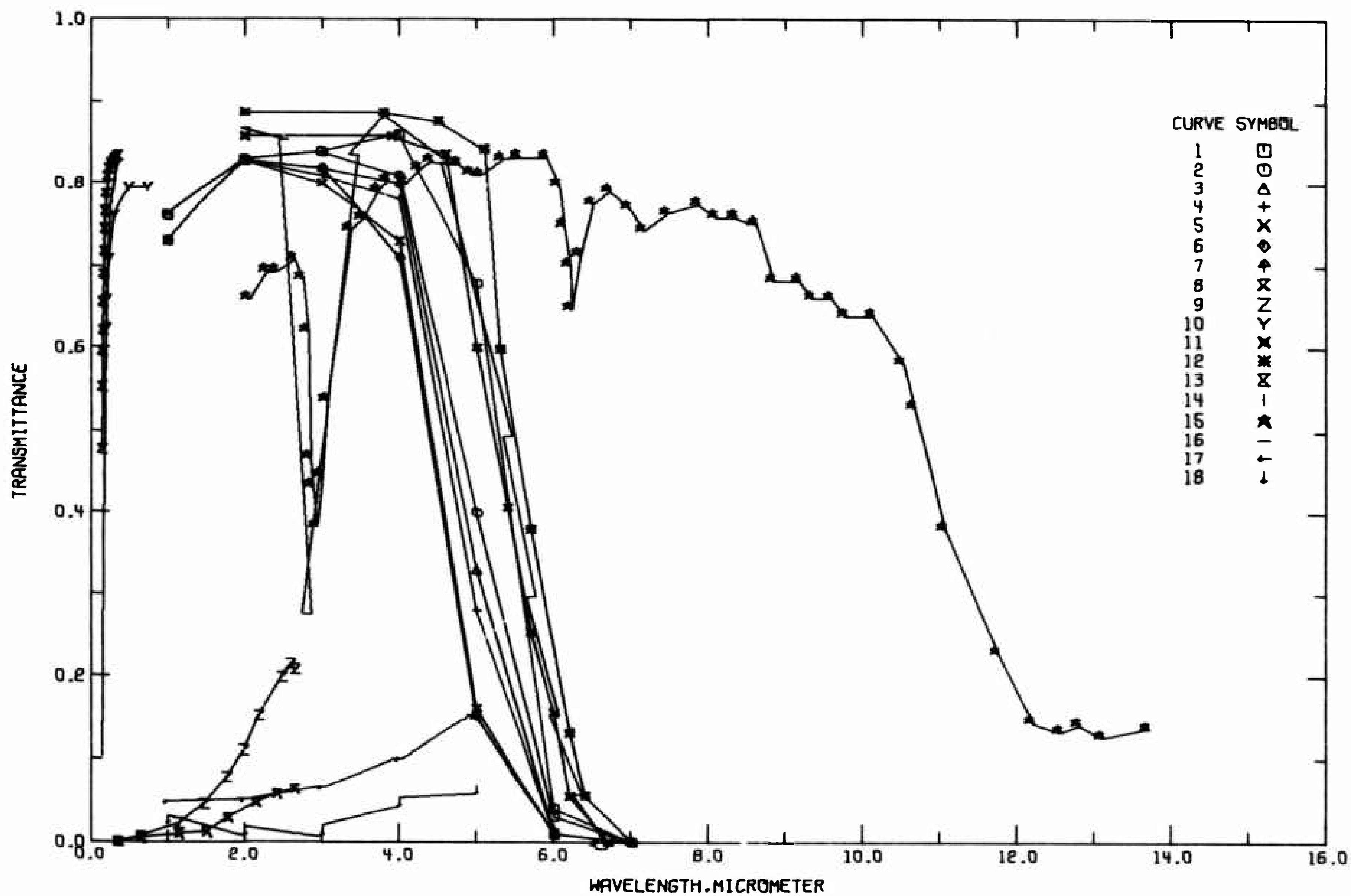


FIGURE 6-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE).

TABLE 6-15. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF ALUMINUM OXIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T29570	Folweiler, R.C.	1964	1-7	293	Linde	Single crystal from Linde; specimen dimensions 0.125 by 0.5 by 1.5 in.; measurement temperature specified as room temperature, 293 K assigned; $\theta \sim 0°$, $\theta' \sim 0°$; reported error ±5%.
2	T29570	Folweiler, R.C.	1964	1-7	785	Linde	The above specimen.
3	T29570	Folweiler, R.C.	1964	1-7	960	Linde	The above specimen.
4	T29570	Folweiler, R.C.	1964	1-7	1177	Linde	The above specimen.
5	T29570	Folweiler, R.C.	1964	1-7	1411	Linde	The above specimen.
6	T29570	Folweiler, R.C.	1964	1-7	1567	Linde	The above specimen.
7	T29570	Folweiler, R.C.	1964	1-7	1671	Linde	The above specimen.
8	T34908	Schatz, E.A.	1966	0.35-2.7	293		>99 pure; specimen 0.0185 in. thick; compacted powder; compaction pressure 11 800 psi; smooth values from figure.
9	T34908	Schatz, E.A.	1966	0.35-2.7	293		Similar to the above specimen except compaction pressure 75 500 psi.
10	T34913	Forestieri, A.F. and Grimes, H.H.	1966	0.19-0.74	293		High purity α-Al_2O_3; disc specimen 1/10 in. thick and 3/8 in. in diameter; c-axis 60° from the normal of the specimen surface; polished, notched for alignment purposes and annealed in air for 1 hr at 1273 K; surface reflections included; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 0°$, $\theta' = 0°$.
11	T36324	McCarthy, D.E.	1965	2.0-6.7	293	Ruby	0.05 Cr, essentially sapphire with the chromium impurity; synthetic; specimen 6.10 mm thick; flat to 10 fringes or better; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 0°$, $\theta' = 0°$.
12	T36324	McCarthy, D.E.	1965	2.0-7.0	293	Sapphire	Synthetic; specimen 3.0 mm flat; flat to 10 fringes or better; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; lack of absorption band at 2.7 μ, compared to T30100 (see curve No. 39), attributed to this present specimen having impurities eliminated; $\theta = 0°$, $\theta' = 0°$.
13	T45481	Boldt, G.	1965	0.14-0.35	293		Specimen 0.5 mm thick; reflection losses included; smooth values from figure; $\theta \sim 0°$, $\theta' \sim 0°$.
14	T45481	Boldt, G.	1965	0.14-0.35	293		Similar to the above specimen except 2 mm thick.
15	T30470	Brame, E.G., Jr., Margrave, J.L., and Meloche, V.W.	1957	2-16	293		99⁺ pure; rhombohedral crystal structure; disk 1 mm thick and 12 mm in diameter; Baird Associates Model B spectrophotometer used; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K.
16	T30100	McCarthy, D.E.	1963	2.0-6.6	293	Sapphire	Synthetic; specimen 2 mm thick; ground and polished to a flatness of seven fringes or better; reference standard was aluminum mirror; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; Beckman IR-5A used in 2-16 μm range and Beckman IR-7 with CsI interchange used in 12.5-50 μm range; $\theta = 0°$, $\theta' = 0°$.
17	T39365	Hobbs, H.A. and Folweiler, R.C.	1966	1.0-5.0	293	AD-995	Author reports measured transmissivity; data from figure; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 0°$, $\theta' = 0°$, $\omega' = 15/4\pi$.
18	T39365	Hobbs, H.A. and Folweiler, R.C.	1966	1.0-5.0	293	AD-85	Similar to the above specimen.

TABLE 6-16. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 1	
T = 293.	
1.	0.76
2.	0.83
3.	0.84
4.	0.86
5.	0.68
6.	0.04
7.	0.00
CURVE 2	
T = 785.	
1.	0.76
2.	0.83
3.	0.84
4.	0.81
5.	0.40
6.	0.03
7.	0.00
CURVE 3	
T = 960.	
1.	0.76
2.	0.83
3.	0.82
4.	0.80
5.	0.33
6.	0.01
7.	0.00
CURVE 4	
T = 1177.	
1.	0.73
2.	0.83
3.	0.81
4.	0.78
5.	0.28
6.	0.01

λ	τ
CURVE 4 (CONT.)	
7.	0.00
CURVE 5	
T = 1411.	
1.	0.73
2.	0.83
3.	0.80
4.	0.73
5.	0.16
6.	0.01
7.	0.60
CURVE 6	
T = 1567.	
1.	0.73
2.	0.63
3.	0.62
4.	0.71
5.	0.15
6.	0.01
7.	0.0
CURVE 7	
T = 1671.	
1.	0.73
2.	0.83
3.	0.62
4.	0.71
5.	0.15
6.	0.01
7.	0.00
CURVE 8	
T = 293.	
0.350	0.000
0.650	0.004

λ	τ
CURVE 8 (CONT.)	
1.149	0.009
1.508	0.011
1.780	0.027
2.148	0.046
2.419	0.058
2.650	0.064
CURVE 9	
T = 293.	
0.350	0.000
0.649	0.006
1.147	0.021
1.475	0.045
1.765	0.079
1.984	0.110
2.185	0.151
2.479	0.199
2.593	0.215
2.650	0.208
CURVE 10	
T = 293.	
0.193	0.624
0.200	0.659
0.229	0.702
0.305	0.759
0.492	0.794
0.738	0.794
CURVE 11	
T = 293.	
2.	0.858
3.9	0.858
4.6	0.837
5.0	0.600
5.4	0.406
5.7	0.253

λ	τ
CURVE 11 (CONT.)	
6.0	0.154
6.2	0.055
6.7	0.000
CURVE 12	
T = 293.	
2.0	0.887
3.8	0.887
4.5	0.876
5.1	0.843
5.3	0.593
5.7	0.379
6.2	0.130
6.4	0.056
7.0	0.000
CURVE 13	
T = 293.	
0.144	0.476
0.147	0.552
0.149	0.595
0.152	0.621
0.158	0.656
0.165	0.691
0.173	0.718
0.182	0.744
0.191	0.764
0.204	0.766
0.222	0.808
0.239	0.819
0.266	0.825
0.301	0.829
0.326	0.833
0.350	0.835

λ	τ
CURVE 14	
T = 293.	
0.144	0.107
0.147	0.171
0.152	0.243
0.157	0.311
0.162	0.370
0.159	0.443
0.176	0.509
0.181	0.550
0.187	0.587
0.192	0.617
0.198	0.646
0.206	0.678
0.215	0.707
0.223	0.728
0.233	0.746
0.248	0.766
0.261	0.779
0.289	0.793
0.311	0.806
0.333	0.821
0.350	0.829
CURVE 15	
T = 293.	
2.00	0.664
2.23	0.699
2.36	0.699
2.59	0.713
2.70	0.690
2.76	0.625
2.79	0.470
2.82	0.436
2.88	0.386
2.94	0.448
3.01	0.540
3.32	0.747
3.48	0.760
3.68	0.795

λ	τ
CURVE 15 (CONT.)	
3.80	0.808
4.02	0.804
4.21	0.823
4.36	0.833
4.72	0.829
4.88	0.817
5.00	0.815
5.28	0.835
5.49	0.838
5.85	0.838
6.01	0.802
6.08	0.752
6.15	0.736
6.17	0.652
6.20	0.718
6.45	0.778
6.67	0.795
6.92	0.773
7.11	0.746
7.42	0.766
7.62	0.779
8.04	0.752
8.30	0.762
8.56	0.754
8.79	0.688
9.12	0.638
9.29	0.666
9.53	0.666
9.72	0.645
10.07	0.645
10.45	0.586
10.60	0.533
11.00	0.365
11.69	0.233
12.14	0.148
12.50	0.136
12.74	0.145
13.04	0.129
13.63	0.140
14.26	0.124

TABLE 6-16. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ALUMINUM OXIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 15(CONT.)	
14.65	0.145
14.94	0.172
15.43	0.225
15.74	0.280
16.00	0.349
CURVE 16	
T = 293.	
2.0	0.869
2.5	0.855
2.3	0.275
3.4	0.835
3.8	0.883
4.6	0.827
5.4	0.494
5.7	0.297
6.0	0.152
6.3	0.057
6.6	0.000
CURVE 17	
T = 293.	
1.00	0.047
2.00	0.050
3.00	0.066
4.00	0.100
4.97	0.150
CURVE 18	
T = 293.	
1.00	0.0254
2.00	0.0126
3.00	0.0115
4.00	0.0462
5.00	0.0629

4.7. Boron Nitride

Boron nitride is a material that is man-made and has no counterpart in nature. It exists in several forms. There is a soft hexagonal form, a hard cubic form, and a hard hexagonal form. Pure boron nitride sublimes at 3273 K and 1 atmosphere while the commercial forms sublime at 3003 K and one atmosphere [E12808].

The soft hexagonal form has a layer-lattice structure similar to graphite. It can be made in two ways. One method of manufacture is by hot pressing. The second method is by chemical vapor deposition (CVD) with this type also known as pyrolytic boron nitride.

The hard cubic form has a zincblende structure. The density is 3.45 g cm^{-3} [A00014]. Borazon, a trademark of the General Electric Company, is cubic boron nitride manufactured by the GE Specialty Materials Department, Worthington, Ohio. The Russian names for cubic boron nitride are Elbor and Cubonite. The cubic form is harder than diamond and is probably the hardest material on earth.

The hard hexagonal form has a wurtzite structure and only small amounts have been synthesized.

The application of boron nitride includes furnace insulation, high temperature lubrication (the graphite-like form), dielectrics, wave guides, heat shields for plasmas, and nose cone windows.

a. Normal Spectral Emittance (Wavelength Dependence)

A total of 19 sets of experimental data were located for the wavelength dependence of the normal spectral emittance of boron nitride. The data are listed in Table 7-3 and shown in Figures 7-1 and 7-2. Specimen characterization and measurement information for the data are given in Table 7-2.

Seven sets of data are for pyrolytic boron nitride (curves 11-17) specimens manufactured by High Temperature Materials, Inc., of Lowell, Massachusetts. Only for three data sets (curves 15-17) were specimen dimensions given. These three data sets cover a temperature range of 1280 to 2020 K and are very close to each other. A set of provisional values is, therefore, based on curves 15, 16, and 17 with these values valid within the following context: a 0.5 in. thick specimen of polished pyrolytic boron nitride manufactured by High Temperature Materials, Inc., with the surface parallel to the basal planes radiating. The values, within an uncertainty of 15%, hold for temperatures of 1280, 1670, and 2020 K. The provisional values are listed in Table 7-1 and shown in Figure 7-1.

Four sets of data (curves 7, 8, 10, and 18) are for 97% pure boron nitride manufactured by the Carborundum Corporation. The material for curve 9 reported by Browning, [T37478] had a density close to the density of the material for curves 7, 8, 10, and 18 and was, therefore, probably 97% pure.

The crystal structure for the remaining data sets was not reported and, therefore, these sets cannot be used for developing evaluated data.

TABLE 7-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε	λ	ε	λ	ε
PYROLYTIC,POLISH 1.27CM THICK T = 1670		PYROLYTIC,POLISH 1.27CM THICK T = 1670 (CONT.)		PYROLYTIC,POLISH 1.27CM THICK T = 1670 (CONT.)		PYROLYTIC,POLISH 1.27CM THICK T = 1670 (CONT.)	
2.5	0.759	6.3	0.848	9.6	0.834	13.2	0.834
2.6	0.762	6.4	0.808	9.7	0.838	13.3	0.841
2.7	0.765	6.5	0.754	9.8	0.842	13.4	0.847
2.8	0.770	6.6	0.680	9.9	0.845	13.5	0.853
2.9	0.774	6.7	0.620	10.0	0.848	13.6	0.858
3.0	0.778	6.8	0.535	10.1	0.851	13.7	0.863
3.1	0.781	6.9	0.480	10.2	0.854	13.8	0.868
3.2	0.785	7.0	0.442	10.3	0.857	13.9	0.872
3.3	0.789	7.05	0.422	10.4	0.860	14.0	0.876
3.4	0.792	7.10	0.404	10.5	0.863	14.1	0.880
3.5	0.796	7.15	0.389	10.6	0.866	14.2	0.884
3.6	0.799	7.20	0.377	10.7	0.869	14.3	0.888
3.7	0.803	7.25	0.371	10.8	0.872	14.4	0.892
3.8	0.806	7.30	0.369	10.9	0.875	14.5	0.896
3.9	0.810	7.35	0.370	11.0	0.878	14.6	0.900
4.0	0.814	7.40	0.377	11.1	0.881	14.7	0.904
4.1	0.819	7.45	0.387	11.2	0.884	14.8	0.907
4.2	0.824	7.50	0.400	11.3	0.887	14.9	0.911
4.3	0.831	7.55	0.416	11.4	0.890	15.0	0.914
4.4	0.839	7.60	0.443	11.5	0.893		
4.5	0.848	7.70	0.495	11.6	0.896		
4.6	0.856	7.8	0.543	11.7	0.898		
4.7	0.865	7.9	0.592	11.8	0.900		
4.8	0.874	8.0	0.651	11.9	0.902		
4.9	0.884	8.1	0.690	12.0	0.903		
5.0	0.892	8.2	0.718	12.1	0.904		
5.1	0.901	8.3	0.737	12.2	0.904		
5.2	0.909	8.4	0.752	12.3	0.904		
5.3	0.916	8.5	0.763	12.4	0.904		
5.4	0.924	8.6	0.774	12.5	0.903		
5.5	0.931	8.7	0.783	12.6	0.900		
5.6	0.936	8.8	0.791	12.7	0.889		
5.7	0.938	8.9	0.798	12.8	0.871		
5.8	0.940	9.0	0.805	12.9	0.847		
5.9	0.939	9.1	0.811	12.95	0.833		
6.0	0.935	9.2	0.816	12.98	0.829		
6.05	0.930	9.3	0.820	13.0	0.828		
6.1	0.921	9.4	0.825	13.05	0.827		
6.2	0.890	9.5	0.830	13.1	0.828		

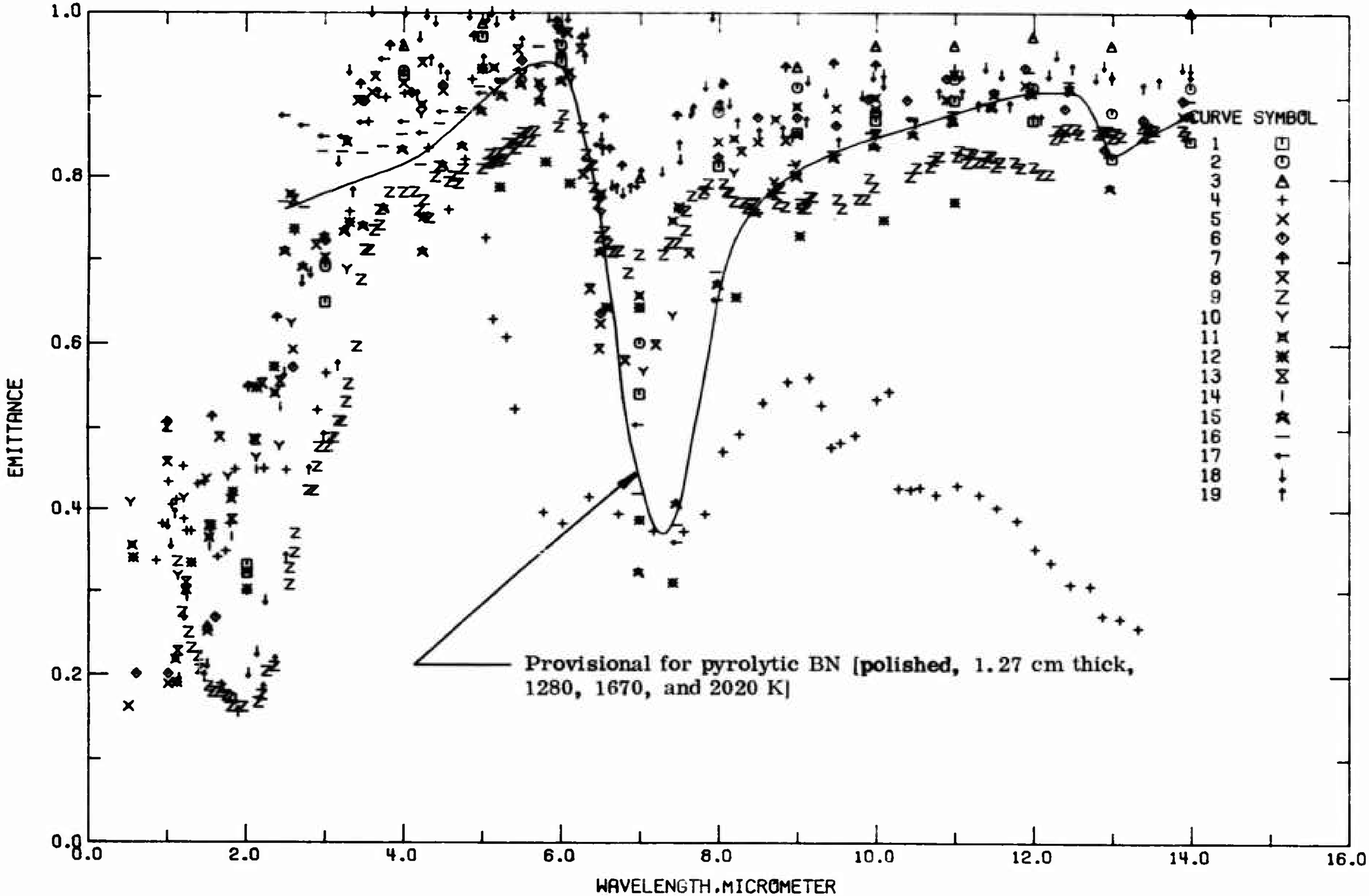


FIGURE 7-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE).

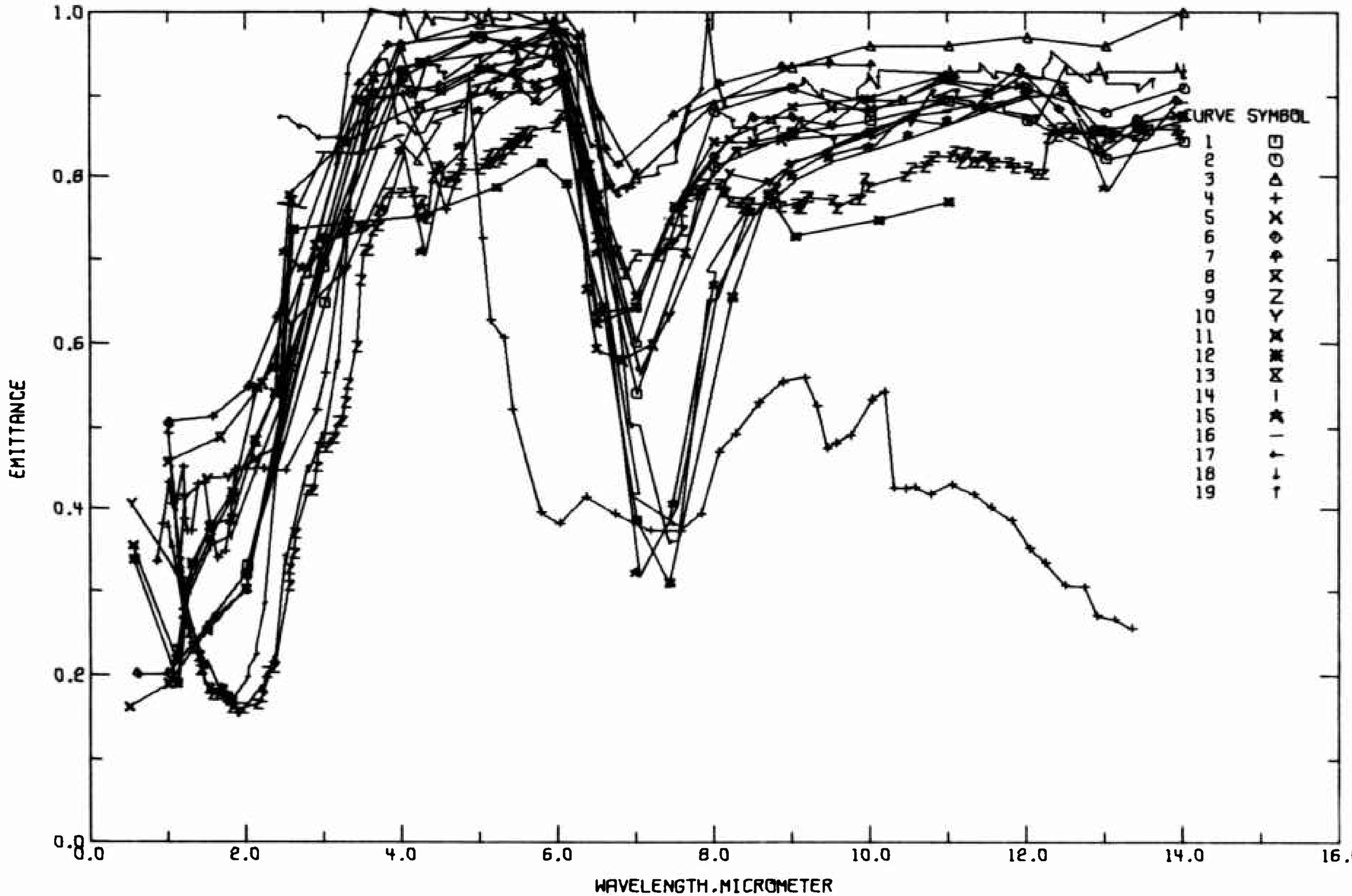


FIGURE 7-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE).

TABLE 7-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T16606	Blau, H.H., Jr., Marsh, J.B., Martin, W.S., Jasperse, J.R., and Chaffee, E.	1960	2-14	873		Measured in air; measurements made with Perkin-Elmer Model 12C Infrared Spectrometer with sodium chloride prism; data from figure; $\theta' = 0°$; reported error ±4%.
2	T16606	Blau, H.H., Jr., et al.	1960	2-14	1083		Similar to the above specimen.
3	T16606	Blau, H.H., Jr., et al.	1960	1.5-14	1353		Similar to the above specimen.
4	T16606	Blau, H.H., Jr., et al.	1960	0.85-13	2273		Specimen heated in air; solar furnace used in attempt to measure spectral reflectance in 1273-3273 K region; data not accurate; data from figure; $\theta' = 0°$.
5	T26088	Walker, G.H. and Casey, F.W., Jr.	1962	0.5-15	1033		Specimen 0.643 cm thick and in form of a semicircle; pressed; machined from 10.15 cm diameter round stock, initial specimens carefully polished on decreasing grits of emery paper to insure a uniform surface, dried at 373 K to remove any absorbed water; $\theta' = 0°$.
6	T26088	Walker, G.H. and Casey, F.W., Jr.	1962	0.6-15	1033		The above specimen, second test.
7	T35502	Grenis, A.F. and Levitt, A.P.	1965	1-10	1300		97.00 BN, 2.40 B_2O_3, 0.20 Al_2O_3 and SiO_2, 0.10 alkaline earth oxides, and 0.008 C; hexagonal crystal structure; machine finished; from Carborundum Co., New Products Branch, Niagara Falls, N.Y.; surface roughness 110 μ in.; bulk density 2.15 g cm^{-3}; measured in vacuum of 35 to 50 μ of pressure; smooth values from figure; $\theta' = 0°$.
8	T35502	Grenis, A.F. and Levitt, A.P.	1965	1-10	1300		Similar to the above specimen except surface finished by polishing with silk cloth.
9	T37478	Browning, M.E.	1963	1.0-15	1273		Sintered; from Carborundum Corp.; density 2.09 g cm^{-3}; reference standard MgO; smooth values from figure; $\theta' = 0°$; reported error ± 5%.
10	T52946	Autio, G.W. and Scala, E.	1968	0.53-11	1098		97.0 BN, 2.40 methanol soluble borate, 0.10 alkaline earth oxides, 0.20 alumina and silica, and 0.008 carbon; polycrystal; hot-pressed; fabricated by Carborundum Co.; surfaces mechanically polished; density 2.1 g cm^{-3}; specimen temperature between 1093 and 1103 K; measured in purified hydrogen atm; probing technique used for measurement; data from figure; $\theta' = 0°$.
11	T52946	Autio, G.W. and Scala, E.	1968	0.55-11	1098	Pyrolytic	Purity < 0.0010 total metallic impurities; measured from A-face (c-axis parallel to surface of $(10\bar{1}0)$ faces); pyrolytic, made by vapor deposition process; prepared by High Temperature Materials, Inc.; surface mechanically polished; density ~2.2 g cm^{-3}; specimen temperature between 1093 and 1103 K; measured in purified hydrogen atm; probing technique used; data from figure; $\theta' = 0°$.
12	T52946	Autio, G.W. and Scala, E.	1968	0.56-11	1098	Pyrolytic	Similar to the above specimen and conditions except measured from C-face (a-axis parallel to surface of (0001) face).
13	T52946	Autio, G.W. and Scala, E.	1968	1.1-2.6	1103	Pyrolytic	Similar to the above specimen and conditions except measured from A-face and polarizer axis parallel to c-axis.
14	T52946	Autio, G.W. and Scala, E.	1968	1.1-2.6	1103	Pyrolytic	Similar to the above specimen and conditions except polarizer axis perpendicular to c-axis.

TABLE 7-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
15	T34724	Durand, J.L. and Houston, K.C.	1966	2.5-15	~1280	Pyrolytic	Specimen size about 2 x 3 x 0.5 in.; manufactured by High Temperature Materials, Inc., Lowell, Mass.; surface polished to a 4-6 μm finish; AB surface (surface parallel to basal planes or planes of deposition) radiating; Beckman IR-9 spectrophotometer used; data from figure; θ' = 0°.
16	T34724	Durand, J.L. and Houston, K.C.	1966	2.5-15	1670	Pyrolytic	Similar to the above specimen.
17	T34724	Durand, J.L. and Houston, K.C.	1966	2.5-15	2020	Pyrolytic	Similar to the above specimen.
18	T22272	Schatz, E.A., Goldberg, D.M., Pearson, E.G., and Burks, T.L.	1963	1-15	1273	Sample No. 97	97 pure; sintered by Carborundum Co.; thickness 50 mils; density 2.09 g cm^{-3}, theoretical density 2.27 g cm^{-3}; smooth values from figure; θ' = 0°.
19	T22272	Schatz, E.A., et al.	1963	1-15	1223	Sample No. 98	100 pure; sintered at 2123 K for 2 hr, setter material BN; density 2.00 g cm^{-3}, theoretical density 2.27 g cm^{-3}; smooth values from figure; θ' = 0°.

TABLE 7-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε
CURVE 1	
T = 873.	
2.00	0.330
3.00	0.648
4.00	0.924
5.00	0.970
6.00	0.940
7.00	0.540
8.00	0.812
9.00	0.855
10.0	0.870
11.0	0.894
12.0	0.870
13.0	0.822
14.0	0.844
CURVE 2	
T = 1083.	
2.00	0.32
3.00	0.69
4.00	0.93
5.00	0.97
6.00	0.96
7.00	0.60
8.00	0.88
9.00	0.91
10.0	0.88
11.0	0.92
12.0	0.91
13.0	0.88
14.0	0.91
CURVE 3	
T = 1353.	
1.50	0.257
2.00	0.320
3.00	0.700
4.00	0.960
5.00	0.986

λ	ε
CURVE 3 (CONT.)	
6.00	0.980
7.00	0.798
8.00	0.890
9.00	0.935
10.0	0.960
11.0	0.960
12.0	0.970
13.0	0.960
14.0	1.000
CURVE 4	
T = 2273.	
0.85	0.335
0.93	0.381
1.01	0.433
1.05	0.405
1.11	0.411
1.20	0.453
1.21	0.387
1.24	0.372
1.30	0.372
1.38	0.430
1.47	0.433
1.54	0.375
1.63	0.339
1.73	0.347
1.79	0.381
1.86	0.449
2.23	0.450
2.51	0.448
2.91	0.522
3.02	0.564
3.31	0.757
3.55	0.868
3.77	0.898
4.01	0.903
4.31	0.835
4.57	0.759
4.78	0.821

λ	ε
CURVE 4 (CONT.)	
4.87	0.920
5.04	0.725
5.14	0.628
5.31	0.607
5.42	0.523
5.78	0.396
6.02	0.382
6.36	0.415
6.73	0.394
7.18	0.373
7.56	0.372
7.83	0.394
8.06	0.471
8.27	0.493
8.57	0.530
8.88	0.554
9.16	0.559
9.31	0.527
9.44	0.476
9.55	0.482
9.74	0.491
10.01	0.534
10.17	0.543
10.29	0.426
10.44	0.425
10.56	0.427
10.76	0.418
11.03	0.430
11.31	0.418
11.53	0.402
11.79	0.386
12.02	0.351
12.22	0.334
12.47	0.307
12.72	0.305
12.88	0.270
13.10	0.266
13.33	0.255

λ	ε
CURVE 5	
T = 1033.	
0.500	0.162
1.00	0.189
1.50	0.251
2.00	0.301
2.60	0.592
3.00	0.702
3.60	0.904
4.00	0.915
4.50	0.906
5.00	0.933
5.50	0.925
6.00	0.952
6.50	0.623
7.00	0.642
7.50	0.762
8.00	0.843
8.50	0.843
9.00	0.852
9.50	0.885
10.0	0.884
10.9	0.896
11.5	0.902
11.9	0.913
12.4	0.857
12.9	0.856
13.4	0.865
13.9	0.876
14.4	0.875
14.9	0.846
CURVE 6	
T = 1033.	
0.600	0.201
1.00	0.201
1.60	0.267
2.00	0.300
2.60	0.571
3.00	0.722

λ	ε
CURVE 6 (CONT.)	
3.50	0.894
4.10	0.904
4.50	0.913
5.00	0.933
5.50	0.943
6.00	0.950
6.50	0.635
7.00	0.642
7.50	0.761
8.00	0.824
8.50	0.874
9.00	0.874
9.50	0.864
9.90	0.896
10.4	0.895
10.9	0.921
11.5	0.904
11.9	0.934
12.4	0.885
12.9	0.834
13.4	0.872
13.9	0.895
14.4	0.875
14.9	0.894
CURVE 7	
T = 1300.	
1.00	0.507
1.57	0.513
2.03	0.548
2.39	0.630
3.45	0.914
3.82	0.960
4.89	0.971
5.94	0.988
6.26	0.969
6.53	0.874
6.61	0.834
6.77	0.813

λ	ε
CURVE 7 (CONT.)	
7.47	0.876
8.06	0.914
8.86	0.935
9.47	0.939
10.0	0.937
CURVE 8	
T = 1300.	
1.00	0.458
1.67	0.488
2.21	0.552
2.89	0.716
3.42	0.894
3.64	0.923
4.24	0.940
5.45	0.955
6.08	0.975
6.25	0.956
6.28	0.802
6.37	0.664
6.49	0.593
6.82	0.579
7.21	0.598
7.63	0.707
7.82	0.782
8.29	0.831
8.86	0.845
10.0	0.854
CURVE 9	
T = 1273.	
1.00	0.500
1.13	0.334
1.19	0.273
1.27	0.250
1.31	0.232
1.39	0.222
1.41	0.206

TABLE 7-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE	9(CONT.)	CURVE	9(CONT.)	CURVE	9(CONT.)	CURVE	9(CONT.)	CURVE	10(CONT.)	CURVE	11(CONT.)
1.52	0.185	4.40	0.799	7.59	0.734	11.47	0.826	1.50	0.437	9.00	0.887
1.57	0.178	4.46	0.812	7.59	0.758	11.52	0.813	1.77	0.439	10.0	0.897
1.65	0.178	4.58	0.793	7.65	0.776	11.58	0.818	2.13	0.463	11.0	0.926
1.69	0.183	4.64	0.800	7.80	0.779	11.77	0.818	2.43	0.477		
1.75	0.174	4.70	0.791	7.88	0.791	11.84	0.811	2.58	0.623	CURVE 12	
1.79	0.171	4.76	0.809	8.07	0.791	12.01	0.812	3.28	0.687	T = 1098.	
1.81	0.161	5.00	0.809	8.11	0.781	12.09	0.803	4.22	0.878		
1.96	0.161	5.08	0.816	8.15	0.781	12.20	0.803	5.15	0.905	0.560	0.338
2.15	0.166	5.11	0.827	8.20	0.769	12.26	0.848	5.75	0.905	1.12	0.190
2.20	0.175	5.15	0.818	8.33	0.768	12.31	0.859	6.12	0.918	1.30	0.332
2.26	0.203	5.20	0.818	8.37	0.761	12.38	0.851	6.51	0.753	1.55	0.378
2.36	0.209	5.21	0.829	8.45	0.766	12.44	0.861	7.05	0.566	1.83	0.420
2.55	0.306	5.29	0.821	8.74	0.767	12.55	0.861	7.42	0.632	2.14	0.547
2.55	0.326	5.33	0.841	8.75	0.786	12.58	0.854	8.20	0.804	2.36	0.571
2.62	0.345	5.38	0.841	8.79	0.786	12.81	0.854	8.71	0.793	2.61	0.735
2.63	0.369	5.42	0.834	8.85	0.763	12.87	0.858	8.99	0.815	3.31	0.743
2.80	0.423	5.45	0.848	9.05	0.767	12.95	0.858	10.0	0.852	4.25	0.750
2.86	0.423	5.51	0.843	9.07	0.761	13.00	0.849	10.9	0.895	5.22	0.786
2.91	0.453	5.52	0.855	9.12	0.761	13.06	0.856			5.80	0.817
2.94	0.477	5.57	0.855	9.16	0.775	13.12	0.851	CURVE 11		6.11	0.791
3.05	0.477	5.61	0.843	9.20	0.775	13.39	0.851	T = 1098.		6.58	0.642
3.09	0.488	5.67	0.857	9.52	0.772	13.48	0.860			7.00	0.386
3.13	0.488	5.97	0.862	9.57	0.761	13.54	0.859	0.550	0.354	7.42	0.309
3.18	0.508	6.03	0.877	9.78	0.772	13.90	0.859	1.10	0.218	8.23	0.654
3.23	0.508	6.28	0.861	9.87	0.772	13.94	0.853	1.23	0.300	8.69	0.779
3.28	0.531	6.32	0.827	9.92	0.798	14.09	0.863	1.53	0.363	9.04	0.727
3.31	0.552	6.35	0.814	9.98	0.787	14.43	0.864	1.81	0.411	10.1	0.746
3.42	0.596	6.40	0.814	10.44	0.800	14.49	0.859	2.11	0.486	11.0	0.768
3.47	0.675	6.42	0.786	10.52	0.811	14.56	0.862	2.37	0.541		
3.52	0.711	6.47	0.766	10.69	0.812	14.82	0.862	2.56	0.777	CURVE 13	
3.57	0.711	6.49	0.726	10.73	0.820	14.87	0.881	3.28	0.842	T = 1103.	
3.63	0.734	6.56	0.732	10.81	0.825	14.94	0.881	4.23	0.889		
3.70	0.740	6.60	0.718	11.03	0.825	15.00	0.886	5.15	0.934	1.13	0.228
3.70	0.759	6.66	0.709	11.07	0.833			5.72	0.915	1.23	0.309
3.82	0.780	6.74	0.710	11.15	0.817	CURVE 10		6.10	0.928	1.53	0.378
4.00	0.780	6.86	0.683	11.20	0.830	T = 1098.		6.51	0.778	1.82	0.386
4.15	0.781	7.00	0.705	11.25	0.829			7.00	0.656	2.13	0.484
4.20	0.758	7.30	0.705	11.29	0.818	0.530	0.407	7.42	0.745	2.44	0.554
4.26	0.771	7.39	0.719	11.38	0.818	1.13	0.317	8.20	0.847	2.60	0.770
4.33	0.749	7.48	0.719	11.42	0.826	1.21	0.413	8.73	0.871		

TABLE 7-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε
CURVE 14	
T = 1103.	
1.14	0.196
1.24	0.292
1.53	0.352
1.81	0.365
2.13	0.448
2.44	0.525
2.61	0.732
CURVE 15	
T = 1280.	
2.49	0.709
2.72	0.690
2.99	0.726
3.24	0.733
3.48	0.739
3.74	0.761
3.98	0.833
4.24	0.709
4.49	0.814
4.74	0.838
4.98	0.882
5.24	0.900
5.48	0.914
5.72	0.894
5.99	0.918
6.49	0.708
6.98	0.322
7.46	0.407
7.99	0.670
8.46	0.757
8.99	0.800
9.46	0.823
9.97	0.838
10.47	0.853
10.97	0.871
11.46	0.887
11.97	0.904
12.46	0.909
CURVE 15 (CONT.)	
12.97	0.786
13.46	0.861
13.99	0.877
14.48	0.854
14.98	0.906
CURVE 16	
T = 1670.	
2.46	0.768
2.73	0.761
2.96	0.830
3.21	0.830
3.47	0.828
3.73	0.837
3.97	0.852
4.21	0.814
4.45	0.866
4.71	0.880
4.96	0.911
5.22	0.920
5.45	0.931
5.71	0.959
5.95	0.983
6.47	0.774
6.97	0.419
7.47	0.380
7.96	0.684
8.46	0.773
8.95	0.814
9.45	0.831
9.94	0.855
10.46	0.873
10.97	0.881
11.44	0.891
11.95	0.929
12.45	0.917
12.96	0.825
13.44	0.867
13.95	0.876
CURVE 16 (CONT.)	
14.46	0.884
14.99	0.917
CURVE 17	
T = 2020.	
2.48	0.875
2.73	0.863
2.98	0.849
3.23	0.849
3.48	0.867
3.75	0.944
4.00	0.868
4.23	0.854
4.49	0.881
4.74	0.885
4.99	0.903
5.23	0.918
5.49	0.932
5.73	0.938
5.98	0.965
6.48	0.839
6.98	0.504
7.47	0.359
7.98	0.651
8.49	0.755
8.98	0.805
9.49	0.827
9.99	0.837
10.46	0.872
10.97	0.865
11.47	0.884
11.97	0.899
12.47	0.903
12.98	0.859
13.47	0.846
13.99	0.894
14.98	0.910
CURVE 18	
T = 1273.	
1.00	0.380
1.04	0.356
1.21	0.270
1.50	0.212
1.68	0.186
1.86	0.170
2.02	0.201
2.13	0.227
2.24	0.288
2.49	0.565
2.71	0.673
2.82	0.683
3.17	0.818
3.31	0.931
3.60	1.000
4.03	1.000
4.21	0.970
4.30	0.997
4.41	0.989
4.84	0.996
5.07	0.993
5.12	1.000
5.18	0.988
5.38	0.996
5.84	0.993
5.93	0.985
6.08	0.993
6.32	0.975
6.51	0.849
6.64	0.789
6.78	0.779
6.96	0.790
7.28	0.806
7.51	0.821
7.65	0.880
7.84	0.912
7.92	0.994
8.03	0.915
8.14	0.891
CURVE 18 (CONT.)	
9.14	0.919
9.37	0.904
9.83	0.901
9.97	0.924
10.1	0.914
10.1	0.927
11.0	0.933
11.1	0.926
11.4	0.935
11.6	0.926
12.2	0.926
12.3	0.949
12.8	0.922
12.9	0.937
13.0	0.925
13.9	0.935
14.0	0.926
14.5	0.934
14.7	0.927
14.8	0.927
14.0	0.945
CURVE 19	
T = 1223.	
1.00	0.500
1.09	0.394
1.20	0.300
1.46	0.197
1.89	0.155
2.21	0.183
2.36	0.217
2.50	0.339
2.80	0.449
2.99	0.490
3.17	0.574
3.35	0.780
3.68	0.903
3.99	0.961
4.17	0.901
CURVE 19 (CONT.)	
4.35	0.943
4.47	0.933
4.55	0.925
5.01	0.944
5.58	0.965
6.01	0.976
6.30	0.945
6.52	0.832
6.70	0.785
6.88	0.785
7.01	0.804
7.50	0.839
7.68	0.884
8.03	0.889
8.24	0.867
8.52	0.855
8.82	0.858
8.94	0.849
9.12	0.869
9.53	0.843
10.0	0.852
10.5	0.867
10.8	0.903
11.1	0.903
11.3	0.888
11.7	0.888
12.0	0.872
12.1	0.872
12.5	0.933
13.0	0.921
13.4	0.910
13.6	0.917
14.1	0.914
14.4	0.902
14.6	0.912
14.8	0.903
14.9	0.925

b. Normal Spectral Emittance (Temperature Dependence)

A total of two sets of experimental data were located for the temperature dependence of the normal spectral emittance. The data are listed in Table 7-6 and shown in Figures 7-3 and 7-4. Specimen characterization and measurement information for the data are given in Table 7-5.

Both sets of data are for 0.650 μm and, therefore, no data from these sources can be used for evaluation at 3.8 and 10.6 μm. However, using the provisional values in the previous section for pyrolytic boron nitride, values for 3.8 and 10.6 μm were obtained for temperatures of 1280, 1670, and 2020 K. The provisional values are listed in Table 7-4 and shown in Figure 7-3. The uncertainty is 15%. The context within which these values are valid is the following: a 0.5 in. thick specimen of polished pyrolytic boron nitride manufactured by High Temperature Materials, Inc., with the surface parallel to the basal planes radiating. Since the provisional values in the previous section are the same for 1280, 1670, and 2022 K, the emittance in this temperature range for either 3.8 or 10.6 μm is temperature independent (see Figure 7-3).

TABLE 7-4. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (TEMPERATURE DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ)

T	ϵ	T	ϵ
PYROLYTIC, POLISHED 1.27CM THICK λ = 3.8		PYROLYTIC, POLISHED 1.27CM THICK λ = 10.6	
1280.	0.805	1280.	0.866
1670.	0.806	1670.	0.866
2020.	0.806	2020.	0.866

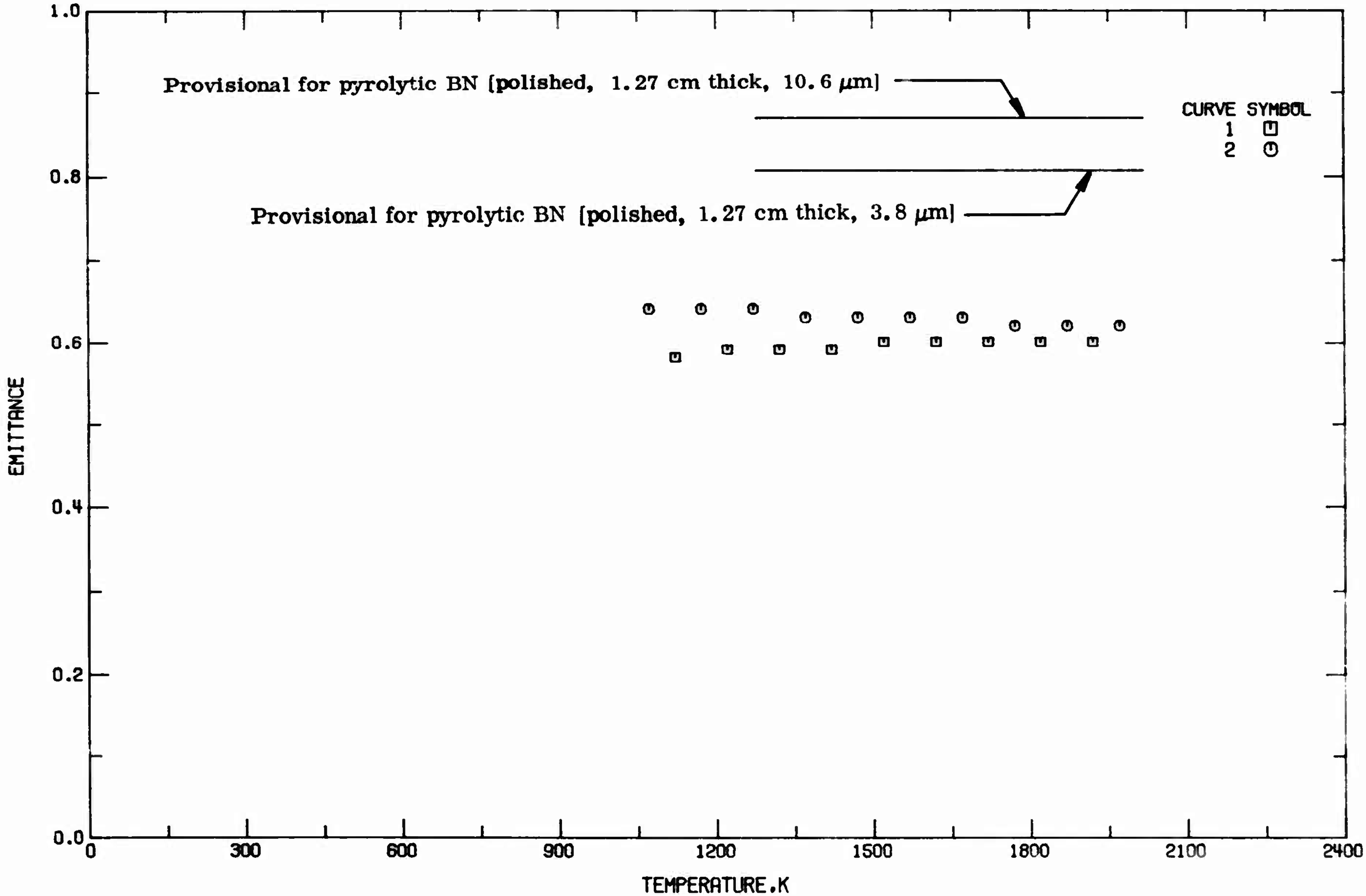


FIGURE 7-3. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (TEMPERATURE DEPENDENCE).

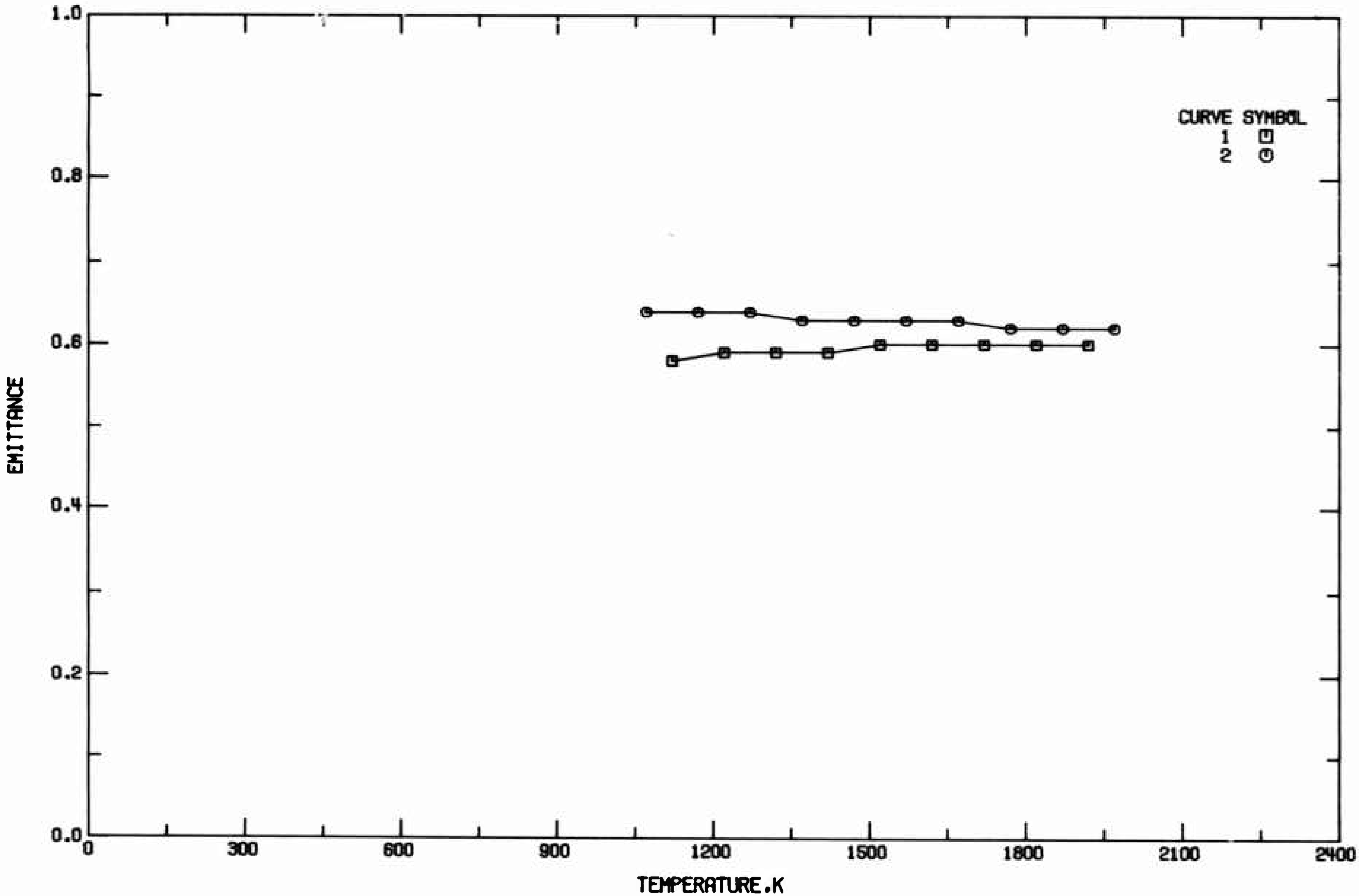


FIGURE 7-4. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (TEMPERATURE DEPENDENCE).

TABLE 7-5. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T14404	Serebryakova, T.I., Paderno, Yu. B., and Samsonov, G.V.	1960	0.650	1123-1923		Layer of paste, approx. 100 μm thick, on tantalum cylinder; paste prepared from fine powder, 2-3 μm, of BN suspended in nitrate binder and dried at 313 to 333 K; $\theta' = 0°$.
2	T32220	Samsonov, G.V., Fomenko, V.S., and Paderno, Yu. B.	1962	0.650	1073-1973		Similar to the above specimen except BN suspended in nitrocellulose binder, applied to outer surface of cylinder, and dried at 313 to 333 K.

TABLE 7-6. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF BORON NITRIDE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ
CURVE 1	
λ = 0.650	
1123.	0.58
1223.	0.59
1323.	0.59
1423.	0.59
1523.	0.60
1623.	0.60
1723.	0.60
1823.	0.60
1923.	0.60
CURVE 2	
λ = 0.650	
1073.	0.64
1173.	0.64
1273.	0.64
1373.	0.63
1473.	0.63
1573.	0.63
1673.	0.63
1773.	0.62
1873.	0.62
1973.	0.62

c. Normal Spectral Reflectance (Wavelength Dependence)

A total of 28 sets of experimental data were located for the wavelength dependence of the normal spectral reflectance of boron nitride. The data are listed in Table 7-9 and shown in Figures 7-5 and 7-6. Specimen characterization and measurement information for the data are given in Table 7-8.

All sets of data, with the exception of one, are for 293 K. No data for higher temperatures was located. Two typical curves are given, one for a pyrolytic specimen and one for a cubic specimen. These are labeled typical because of the lack of complete specimen dimensions and the uncertainty of these values can be 30% or larger. The typical curve for pyrolytic boron nitride at 293 K is based on curve 2 and holds for a specimen from High Temperature Materials, Inc., for linearly polarized light with the electric field vector parallel to the c-axis of the crystal, and $\theta = 0°$ and $\theta' = 0°$. The typical curve for cubic boron nitride at 293 K is based on curve 5 and holds for a polished specimen with density approaching the theoretical value of 3.50 g cm^{-3}. The typical values are listed in Table 7-7 and shown in Figure 7-5.

TABLE 7-7. TYPICAL NORMAL SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ	λ	ρ	λ	ρ	λ	ρ
PYROLYTIC		PYROLYTIC		CUBIC POLISHED		CUBIC POLISHED	
T = 293		T = 293 (CONT.)		T = 293		T = 293 (CONT.)	
5.00	0.092	10.0	0.114	5.040	0.096	9.268	0.817
5.10	0.089	10.2	0.110	5.260	0.097	9.320	0.817
5.21	0.087	10.6	0.098	5.457	0.094	9.407	0.816
5.33	0.084	11.0	0.088	5.747	0.089	9.434	0.806
5.44	0.081	11.2	0.082	5.956	0.080	9.569	0.737
5.56	0.071	11.4	0.065	6.00	0.077	9.681	0.661
5.68	0.064	11.7	0.044	6.101	0.075	9.814	0.586
5.80	0.056	11.9	0.025	6.295	0.067	9.950	0.501
5.95	0.042	12.0	0.010	6.447	0.059	10.00	0.487
6.0	0.039	12.1	0.049	6.540	0.047	10.12	0.451
6.09	0.036	12.3	0.478	6.784	0.039	10.33	0.410
6.17	0.053	12.3	0.702	6.954	0.025	10.62	0.373
6.24	0.085	12.7	0.774	7.00	0.021	10.88	0.350
6.29	0.120	12.9	0.580	7.082	0.016	11.00	0.342
6.33	0.168	13.0	0.490	7.143	0.012	11.14	0.332
6.37	0.219	13.1	0.408	7.225	0.012	11.55	0.313
6.39	0.268	13.2	0.333	7.299	0.019	12.00	0.297
6.44	0.305	13.5	0.291	7.364	0.028	12.02	0.296
6.47	0.329	13.6	0.262	7.402	0.059	12.56	0.280
6.58	0.345	14.0	0.224	7.452	0.165	13.00	0.271
6.66	0.328	14.3	0.212	7.524	0.307	13.30	0.264
6.76	0.289	14.8	0.200	7.570	0.410	14.27	0.249
6.84	0.260	15.3	0.194	7.628	0.537	15.02	0.240
6.93	0.238	16.2	0.175	7.675	0.641	16.03	0.231
7.0	0.228	17.3	0.172	7.722	0.728		
7.05	0.221	18.6	0.157	7.749	0.771		
7.12	0.202	20.1	0.162	7.843	0.789		
7.26	0.189	21.7	0.159	7.987	0.805		
7.47	0.177	23.9	0.159	8.00	0.806		
7.69	0.163	26.4	0.157	8.091	0.816		
7.94	0.160	29.9	0.153	8.137	0.820		
8.0	0.157	33.3	0.152	8.333	0.820		
8.22	0.148			8.496	0.810		
8.50	0.144			8.643	0.801		
8.84	0.143			8.787	0.798		
9.0	0.137			8.929	0.798		
9.10	0.133			9.00	0.801		
9.46	0.126			9.107	0.806		
9.83	0.116			9.200	0.813		

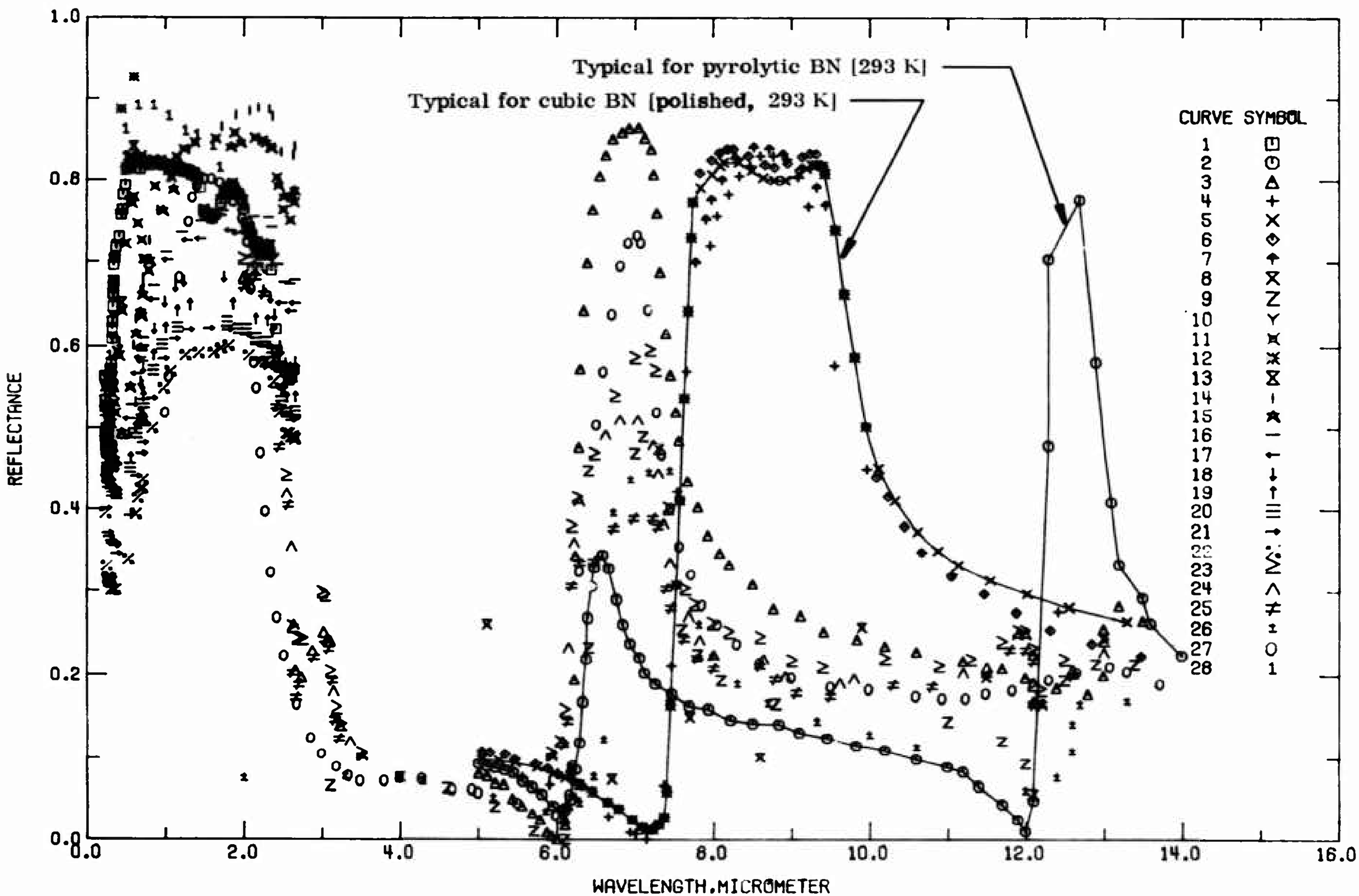


FIGURE 7-5. TYPICAL NORMAL SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE).

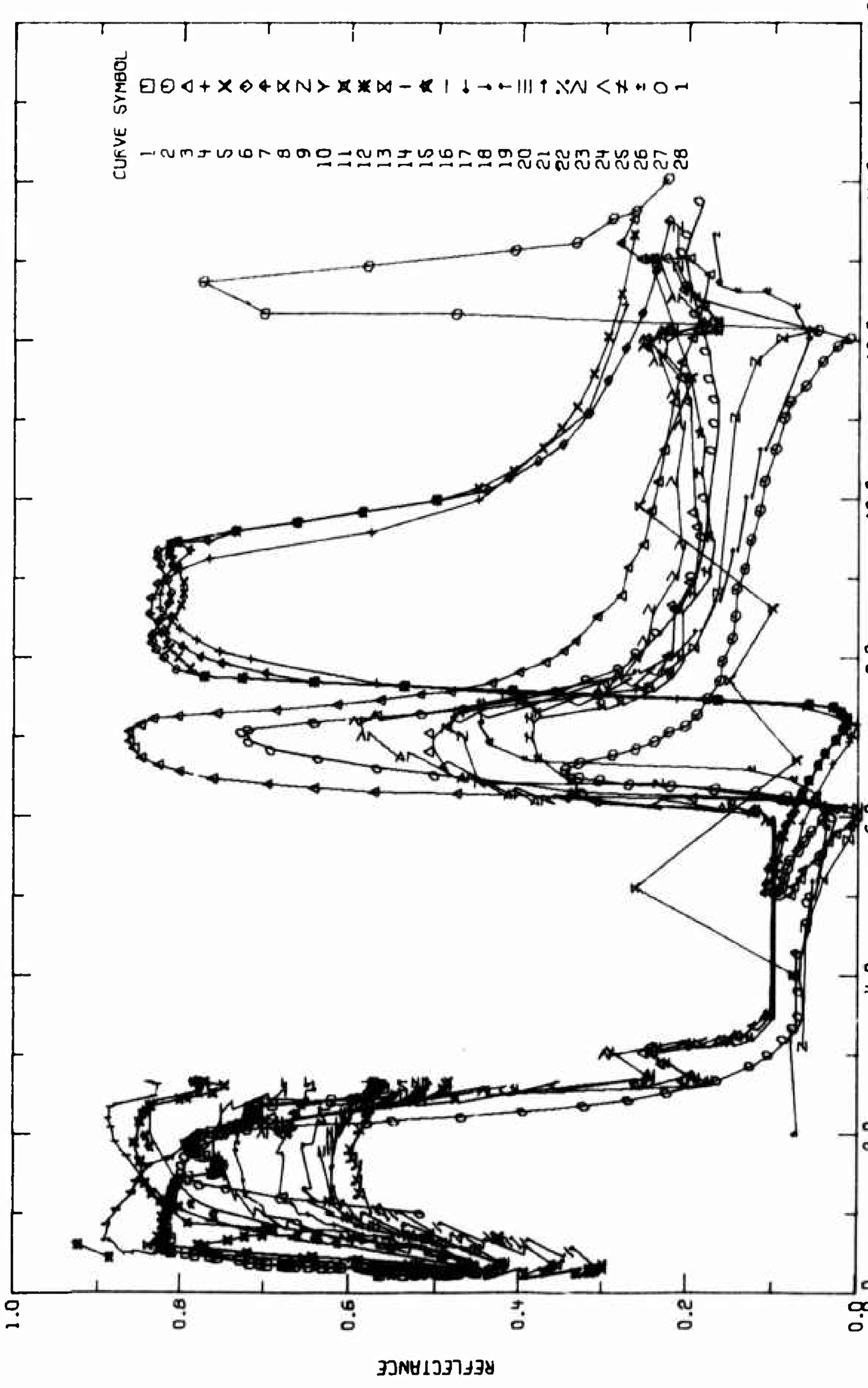


FIGURE 7-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE).

TABLE 7-8. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF BORON NITRIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T37478	Browning, M. E.	1963	0.23-2.65	293		Sintered; from Carborundum Corp.; density 2.09 g cm^{-3}; reference standard MgO; smooth values from figure; integrating sphere reflectometer, Beckman DK-2a spectroreflectometer, used; author reports spectral total reflectance; $\theta = \sim 5°$, $\omega' = 2\pi$.
2	T39203	Geick, R., Perry, C.H., and Rupprecht, G.	1966	5-33	293	Pyrolytic	Hexagonal structure; samples supplied by High Temperature Materials, Inc.; linearly polarized light used with $\vec{E}$ parallel to c-axis of crystal; Perkin-Elmer Model 521 spectrophotometer with reflection attachment used; measurement temperature not given explicitly, assumed to be 293 K; smooth values from figure; $\theta=0°$, $\theta'=0°$.
3	T39203	Geick, R., et al.	1966	5-33	293	Pyrolytic	Similar to the above specimen except linearly polarized light used with $\vec{E}$ perpendicular to c-axis of crystal.
4	T42872	Gielisse, P.J., Mitra, S.S., Plendl, J.N., Griffis, R.D., Mansur, L.C., Marshall, R., and Pascoe, E.A.	1967	5.6-25	293		Cubic boron nitride; specimen approx. 6 mm in diameter; specimen manufactured by being subjected to very high pressures and temperatures; opaque; density approaches theoretical value of 3.50 g cm^{-3}; ground and polished on one side with successively finer diamond powder to a perfectly flat, homogeneous, mirror-like finish; Perkin-Elmer Model 521 and 221 infrared spectrophotometers, together with appropriate attachments, used to measure reflectivity; data from figure; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 0°$, $\theta' = 0°$.
5	T42872	Gielisse, P.J., et al.	1967	5.0-16	293		Similar to the above specimen except smooth values from figure.
6	T42872	Gielisse, P.J., et al.	1967	5.0-13	77		Similar to the above specimen except measured at liquid nitrogen temperature, 77.3 K.
7	T42872	Gielisse, P.J., et al.	1967	6.3-10	293		Similar to the above specimen except annealed in air at 623 K for 15 min and subsequently measured at room temperature, 293 K assigned.
8	T40528	Sulzbach, F. and Turner, A.F.	1966	4.0-34	293		Film; optical thickness 10 quarterwaves at $\lambda = 1.7$ μm; electron beam deposited in vacuum, 2-8 x 10^{-5} mm Hg, at normal incidence onto glass substrate heated to 588 K; rate of depositing 1 quarterwave per min at $\lambda = 0.5$ μm; clear dark brown in appearance; measurements made at room temperature, 293 K assigned; Perkin-Elmer Models 21 and 221 spectrophotometers used; data from figure; $\theta = 0°$.
9	T40528	Sulzbach, F. and Turner, A.F.	1966	3.1-37	293		Polished; massive BN; measurements made at room temperature, 293 K assigned; Perkin-Elmer Models 21 and 221 spectrophotometers used; smooth values from figure; $\theta = 0°$.
10	T22272	Schatz, E.A., Goldberg, D.M., Pearson, E.G., and Burks, T.L.	1963	0.23-2.7	293	Sample No. 97	97 pure; sintered specimen; from Carborundum Co.; density 2.09 g cm^{-3}, theoretical density 2.27 g cm^{-3}; thickness 50 mils; reference standard MgO, reflectance data measured and presented relative to MgO; spectral total reflectance reported; integrating sphere reflectometer, Beckman DK-2a spectroreflectometer used; measurement temperature not given explicitly, 293 K assigned; smooth values from figure; $\theta = \sim 5°$, $\omega'=2\pi$.
11	T22272	Schatz, E.A., et al.	1963	0.23-2.7	293	Sample No. 98	100 pure; sintered at 2123 K for 2 hr, setter material BN; density 2.00 g cm^{-3}, theoretical density 2.27 g cm^{-3}; thickness 65 mils; reference standard MgO, reflectance data measured and presented relative to MgO; spectral total reflectance reported; integrating sphere reflectometer, Beckman DK-2a spectroreflectometer used; measurement temperature not explicitly given, 293 K assigned; smooth values from figure; $\theta = \sim 5°$, $\omega'=2\pi$.

TABLE 7-8. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF BORON NITRIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
12	T28755	Zerlaut, G.A. and Harada, Y.	1963	0.44, 0.60	293	HC 0021	Manufactured by Carborundum Co.; powder compacted at 10 000 psi; MgO used as standard, absolute values of reflectance reported; integrating sphere reflectometer used; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 0°$, $\omega' = 2\pi$.
13	T28755	Zerlaut, G.A. and Harada, Y.	1963	0.44, 0.60	293	HC 0021	The above specimen and conditions except exposed to uv irradiation; 75 ESH with solar factor 1.5.
14	T37398	Schatz, E.A., Counts, C.R., III, and Burks, T.L.	1964	0.23-2.7	293		99.5 pure powder; from Carborundum Co.; mesh size 325; compacted at 290 psi with highly polished stainless steel ram; curves measured and presented relative to freshly prepared smoked MgO reference samples; Beckman DK-2A spectroreflectometer used; measurement temperature not given explicitly, assumed to be 293 K; smooth values from figure; $\theta = 0°$, $\omega' = 2\pi$; reported error ± 3%.
15	T37398	Schatz, E.A., et al.	1964	0.23-2.7	293		Similar to the above specimen except compacted at 1150 psi.
16	T37398	Schatz, E.A., et al.	1964	0.23-2.7	293		Similar to the above specimen except compacted at 2880 psi.
17	T37398	Schatz, E.A., et al.	1964	0.23-2.7	293		Similar to the above specimen except compacted at 5760 psi.
18	T37398	Schatz, E.A., et al.	1964	0.23-2.7	293		Similar to the above specimen except compacted at 11 500 psi.
19	T37398	Schatz, E.A., et al.	1964	0.23-2.7	293		Similar to the above specimen except compacted at 20 200 psi.
20	T37398	Schatz, E.A., et al.	1964	0.23-2.7	293		Similar to the above specimen except compacted at 28 800 psi.
21	T37398	Schatz, E.A., et al.	1964	0.23-2.7	293		Similar to the above specimen except compacted at 31 700 psi.
22	T37398	Schatz, E.A., et al.	1964	0.23-2.7	293		Similar to the above specimen except compacted at 34 600 psi.
23	T37398	Schatz, E.A., et al.	1964	2.0-15	293		Commercial sintered sample; surface machine grooved to roughness 35-40 μm; black-body reflectometer used in conjunction with Baird-Atomic Model NK-1 spectrophotometer; reflectance factor ($\omega = 2\pi$; $\theta' = 0°$) actually measured, equated to reflectance ($\theta = 0°$; $\omega' = 2\pi$); smooth values from figure.
24	T37398	Schatz, E.A., et al.	1964	2.0-15	293		Similar to the above specimen except surface roughness 300-400 μm.
25	T37398	Schatz, E.A., et al.	1964	2.0-36	293		Similar to the above specimen except surface roughness 1800-2200 μm.
26	T27586	Martin, T.P., Massa, J.D., and Turner, A.F.	1963	2-36	293		Pressed powder; measurement temperature not given explicitly, assumed to be 293 K; smooth values from figure; $\theta = 0°$.
27	A00027, A00002	Cunnington, G.R.	1975	1.0-24	293		97.0 BN, 2.4 boric oxide, 0.2 alumina and silica, 0.1 alkaline earth oxides, and < 0.01 carbon (this typical composition given by supplier); manufactured by Carborundum Co.; hot-pressed; no specification of density give[illegible]; G.D. heated cavity used for measurement; reflectance f[illegible]tor with $\omega = 2\pi$, $\theta' = 20°$ actually measured, equated here to reflectance with $\theta = 20°$, $\omega' = 2\pi$; measurement temperature not given explicitly, assumed to be 293 K.
28	A00027, A00002	Cunnington, G.R.	1975	0.29-2.11	293		97.00 BN, 2.4 boric oxide, 0.2 alumina and silica, 0.1 alkaline earth oxides, and < 0.01 carbon (this typical composition given by supplier); manufactured by Carborundum Co.; hot-pressed; no specification of density given; G.D. integrating sphere used for measurement; reflectance factor measured; direct or indirect made not explicitly given, direct made with $\theta = 20°$, $\omega' = 2\pi$ presumed; measurement temperature not given explicitly, assumed to be 293 K.

TABLE 7-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
CURVE 1		CURVE 1(CONT.)		CURVE 1(CONT.)		CURVE 1(CONT.)		CURVE 2(CONT.)		CURVE 3	
T = 293.										T = 293.	
		0.4170	0.729	1.461	0.788	2.437	0.594	8.22	0.148		
0.230	0.563	0.4440	0.755	1.504	0.760	2.471	0.574	8.50	0.144	5.00	0.080
0.2328	0.535	0.4620	0.762	1.521	0.758	2.498	0.574	8.84	0.143	5.11	0.077
0.2402	0.495	0.4720	0.780	1.536	0.753	2.545	0.568	9.10	0.133	5.21	0.069
0.2425	0.483	0.5020	0.792	1.579	0.753	2.587	0.559	9.46	0.126	5.32	0.067
0.2458	0.476	0.5210	0.811	1.607	0.750	2.620	0.562	9.83	0.116	5.43	0.051
0.2491	0.472	0.5550	0.813	1.638	0.756	2.650	0.571	10.2	0.110	5.55	0.042
0.2547	0.472	0.5690	0.824	1.653	0.755			10.6	0.098	5.68	0.033
0.2558	0.474	0.5950	0.824	1.721	0.769	CURVE 2		11.0	0.088	5.78	0.025
0.2580	0.469	0.6070	0.822	1.728	0.774	T = 293.		11.2	0.082	5.87	0.009
0.2603	0.472	0.6500	0.822	1.764	0.781			11.4	0.065	5.93	0.004
0.2662	0.475	0.6700	0.821	1.783	0.785	5.00	0.092	11.7	0.044	6.00	0.000
0.2679	0.479	0.6840	0.811	1.815	0.785	5.10	0.089	11.9	0.025	6.10	0.018
0.2724	0.488	0.6960	0.824	1.827	0.783	5.21	0.087	12.0	0.010	6.09	0.026
0.2750	0.493	0.7500	0.819	1.841	0.789	5.33	0.084	12.1	0.049	6.13	0.043
0.2757	0.501	0.8140	0.816	1.864	0.792	5.44	0.081	12.3	0.478	6.18	0.087
0.2799	0.514	0.8280	0.820	1.888	0.788	5.56	0.071	12.3	0.702	6.22	0.194
0.2816	0.517	0.9510	0.820	1.897	0.784	5.68	0.064	12.7	0.774	6.23	0.344
0.2823	0.521	0.9730	0.816	1.911	0.783	5.80	0.056	12.9	0.580	6.28	0.476
0.2850	0.526	0.9860	0.817	1.921	0.780	5.95	0.042	13.1	0.408	6.30	0.572
0.2889	0.545	1.054	0.815	1.955	0.780	6.09	0.036	13.2	0.333	6.34	0.642
0.2913	0.552	1.066	0.813	1.994	0.774	6.17	0.050	13.5	0.291	6.39	0.697
0.2938	0.552	1.111	0.812	2.017	0.762	6.24	0.085	13.6	0.262	6.46	0.762
0.2983	0.562	1.125	0.814	2.051	0.745	6.29	0.120	14.0	0.224	6.55	0.803
0.3006	0.571	1.150	0.810	2.071	0.739	6.33	0.168	14.3	0.212	6.63	0.829
0.3046	0.571	1.176	0.810	2.084	0.739	6.37	0.219	14.8	0.200	6.72	0.849
0.3069	0.569	1.183	0.813	2.098	0.731	6.39	0.268	15.3	0.194	6.84	0.857
0.3113	0.579	1.193	0.813	2.115	0.731	6.44	0.305	16.2	0.175	6.93	0.862
0.3200	0.608	1.212	0.810	2.150	0.721	6.47	0.329	17.3	0.172	7.05	0.863
0.3247	0.621	1.238	0.810	2.166	0.717	6.58	0.345	18.6	0.157	7.13	0.850
0.3258	0.629	1.249	0.809	2.185	0.717	6.66	0.328	20.1	0.162	7.21	0.836
0.3276	0.629	1.266	0.809	2.223	0.711	6.76	0.289	21.7	0.159	7.24	0.805
0.3338	0.646	1.283	0.811	2.249	0.706	6.84	0.260	23.9	0.159	7.28	0.758
0.3400	0.660	1.296	0.808	2.269	0.706	6.93	0.238	26.4	0.157	7.32	0.686
0.3410	0.660	1.318	0.810	2.283	0.711	7.05	0.221	29.9	0.153	7.39	0.615
0.3436	0.568	1.345	0.804	2.308	0.718	7.12	0.202	33.3	0.152	7.45	0.565
0.3500	0.575	1.359	0.807	2.325	0.718	7.26	0.189			7.52	0.528
0.3500	0.694	1.385	0.807	2.344	0.710	7.47	0.177			7.56	0.484
0.3660	0.703	1.399	0.802	2.367	0.688	7.69	0.163			7.67	0.435
0.3750	0.716	1.428	0.802	2.423	0.620	7.94	0.160			7.80	0.402

TABLE 7-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE	3(CONT.)
7.93	0.369
8.08	0.347
8.20	0.333
8.50	0.308
6.77	0.279
9.12	0.271
9.41	0.252
9.84	0.243
10.2	0.235
10.6	0.228
11.2	0.217
11.7	0.208
12.0	0.196
12.4	0.184
12.8	0.177
13.0	0.199
13.0	0.256
13.2	0.282
13.5	0.265
14.3	0.239
15.3	0.228
16.2	0.221
17.3	0.215
18.6	0.215
20.0	0.211
21.9	0.211
24.0	0.208
26.4	0.205
29.4	0.205
33.3	0.203
CURVE 4	
T = 293.	
5.555	0.075
5.903	0.067
6.231	0.352
6.653	0.029
6.930	0.009
6.998	0.007

λ	ρ
CURVE	4(CONT.)
7.143	0.000
7.220	0.016
7.369	0.066
7.463	0.211
7.536	0.422
7.663	0.569
7.962	0.718
8.052	0.754
8.203	0.781
8.340	0.803
8.475	0.816
8.606	0.828
8.772	0.828
8.945	0.824
9.091	0.802
9.225	0.766
9.560	0.576
9.970	0.450
11.06	0.321
12.42	0.275
14.22	0.251
16.64	0.232
19.96	0.225
25.00	0.217
CURVE 5	
T = 293.	
5.040	0.098
5.260	0.097
5.467	0.094
5.747	0.088
5.956	0.080
6.101	0.075
6.285	0.067
6.447	0.059
6.640	0.047
6.784	0.039
6.954	0.025
7.082	0.016

λ	ρ
CURVE	5(CONT.)
7.143	0.012
7.225	0.012
7.299	0.019
7.364	0.028
7.402	0.059
7.452	0.165
7.524	0.307
7.570	0.410
7.628	0.537
7.675	0.641
7.722	0.728
7.740	0.771
7.843	0.789
7.987	0.805
8.091	0.816
8.137	0.820
8.333	0.820
8.496	0.810
8.643	0.801
8.787	0.798
8.929	0.798
9.107	0.806
9.200	0.813
9.268	0.817
9.320	0.817
9.407	0.816
9.434	0.806
9.569	0.737
9.681	0.661
9.814	0.586
9.960	0.501
10.12	0.451
10.33	0.410
10.62	0.373
10.88	0.350
11.14	0.332
11.55	0.313
12.02	0.296
12.56	0.280
13.30	0.264

λ	ρ
CURVE	5(CONT.)
14.27	0.249
15.02	0.240
16.03	0.231
CURVE 6	
T = 77.	
5.040	0.108
5.144	0.107
5.336	0.105
5.459	0.098
5.727	0.092
5.879	0.086
6.010	0.079
6.150	0.073
6.309	0.066
6.447	0.059
6.640	0.047
6.784	0.039
6.954	0.025
7.082	0.016
7.143	0.012
7.225	0.012
7.299	0.019
7.364	0.028
7.402	0.059
7.452	0.165
7.524	0.307
7.570	0.410
7.628	0.537
7.675	0.641
7.722	0.728
7.740	0.771
7.831	0.807
7.981	0.823
8.084	0.832
8.183	0.837
8.264	0.837
8.453	0.828
8.666	0.817

λ	ρ
CURVE	6(CONT.)
8.787	0.814
8.953	0.819
9.141	0.827
9.242	0.831
9.320	0.831
9.407	0.816
9.434	0.806
9.569	0.737
9.681	0.661
9.814	0.586
9.960	0.501
10.09	0.440
10.24	0.415
10.45	0.379
10.67	0.348
11.05	0.318
11.47	0.296
11.88	0.274
12.32	0.254
12.85	0.238
13.48	0.223
CURVE 7	
T = 293.	
6.258	0.067
6.285	0.067
6.447	0.059
6.640	0.047
6.784	0.039
6.954	0.025
7.082	0.016
7.143	0.012
7.225	0.012
7.299	0.019
7.364	0.028
7.402	0.059
7.452	0.165
7.524	0.307
7.570	0.410

λ	ρ
CURVE	7(CONT.)
7.628	0.537
7.675	0.641
7.776	0.697
7.905	0.750
7.981	0.774
8.117	0.798
8.285	0.825
8.525	0.839
8.718	0.837
8.897	0.830
9.132	0.812
9.328	0.789
9.434	0.806
9.443	0.767
9.569	0.737
9.681	0.661
9.814	0.586
9.960	0.501
CURVE 8	
T = 293.	
4.00	0.075
5.10	0.260
6.70	0.073
7.70	0.151
8.60	0.100
9.90	0.257
11.5	0.196
13.0	0.244
14.8	0.273
18.0	0.361
19.3	0.415
20.9	0.260
23.4	0.094
24.4	0.141
25.4	0.088
27.0	0.145
30.1	0.145
34.0	0.142

TABLE 7-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, µm; TEMPERATURE, T, K; REFLECTANCE, ρ]

CURVE 9
T = 293.

λ	ρ
3.10	0.066
4.60	0.063
5.20	0.041
5.70	0.010
6.10	0.000
6.40	0.233
6.40	0.448
7.00	0.469
7.10	0.483
7.30	0.474
7.60	0.255
7.80	0.225
8.10	0.193
8.80	0.166
11.0	0.146
11.7	0.122
12.0	0.092
12.1	0.056
12.5	0.193
12.9	0.213
13.4	0.213
14.3	0.179
14.9	0.135
15.4	0.101
16.1	0.087
33.4	0.082
34.8	0.062
35.5	0.043
36.4	0.045
37.0	0.057

CURVE 10
T = 293.

λ	ρ
0.230	0.562
0.240	0.494
0.250	0.470
0.260	0.470
0.270	0.483

CURVE 10 (CONT.)

λ	ρ
0.280	0.514
0.290	0.550
0.300	0.570
0.310	0.570
0.320	0.607
0.330	0.635
0.340	0.660
0.345	0.663
0.350	0.675
0.350	0.700
0.379	0.719
0.447	0.757
0.513	0.813
0.548	0.813
0.569	0.827
0.673	0.823
0.683	0.811
0.700	0.828
0.789	0.818
0.854	0.823
0.950	0.823
1.05	0.819
1.15	0.812
1.35	0.807
1.44	0.799
1.50	0.762
1.53	0.754
1.60	0.749
1.79	0.786
1.83	0.785
1.86	0.794
1.91	0.781
1.99	0.773
2.10	0.731
2.26	0.707
2.32	0.718
2.36	0.699
2.45	0.586
2.47	0.573
2.55	0.566
2.60	0.559
2.65	0.570

CURVE 11
T = 293.

λ	ρ
0.230	0.550
0.233	0.529
0.236	0.499
0.245	0.452
0.260	0.486
0.280	0.472
0.290	0.476
0.294	0.473
0.300	0.467
0.310	0.504
0.319	0.543
0.327	0.562
0.340	0.550
0.350	0.531
0.360	0.518
0.387	0.592
0.413	0.587
0.448	0.641
0.497	0.720
0.551	0.772
0.582	0.769
0.603	0.777
0.652	0.744
0.702	0.724
0.721	0.701
0.757	0.701
0.789	0.687
0.875	0.790
1.04	0.809
1.08	0.801
1.15	0.826
1.24	0.836
1.38	0.844
1.65	0.849

CURVE 11 (CONT.)

λ	ρ
1.89	0.856
2.15	0.850
2.25	0.847
2.35	0.838
2.43	0.801
2.51	0.761
2.60	0.748
2.65	0.770

CURVE 12
T = 293.

λ	ρ
0.440	0.885
0.600	0.925

CURVE 13
T = 293.

λ	ρ
0.440	0.650
0.600	0.840

CURVE 14
T = 293.

λ	ρ
0.230	0.540
0.240	0.479
0.243	0.475
0.245	0.460
0.249	0.462
0.253	0.453
0.259	0.457
0.264	0.454
0.272	0.460
0.276	0.459
0.285	0.466
0.291	0.463
0.298	0.466
0.302	0.461
0.322	0.461
0.332	0.469

CURVE 14 (CONT.)

λ	ρ
0.350	0.467
0.360	0.477
0.589	0.600
0.618	0.632
0.681	0.664
0.703	0.662
0.717	0.671
0.717	0.679
0.800	0.724
0.901	0.761
1.05	0.801
1.30	0.835
1.72	0.864
1.90	0.878
2.08	0.883
2.19	0.887
2.33	0.885
2.37	0.876
2.48	0.833
2.63	0.829
2.65	0.840

CURVE 15
T = 293.

λ	ρ
0.230	0.526
0.236	0.492
0.252	0.450
0.261	0.452
0.288	0.462
0.308	0.453
0.330	0.459
0.350	0.461
0.441	0.493
0.549	0.550
0.624	0.614
0.679	0.639
0.698	0.635
0.712	0.659
0.801	0.699

CURVE 15 (CONT.)

λ	ρ
0.976	0.760
1.11	0.786
1.32	0.808
1.84	0.839
1.97	0.844
2.29	0.844
2.36	0.837
2.45	0.791
2.52	0.777
2.62	0.778
2.65	0.785

CURVE 16
T = 293.

λ	ρ
0.230	0.526
0.236	0.492
0.252	0.450
0.261	0.452
0.288	0.462
0.308	0.453
0.330	0.459
0.341	0.457
0.360	0.456
0.452	0.486
0.558	0.529
0.671	0.596
0.695	0.593
0.699	0.599
0.706	0.609
0.850	0.670
1.01	0.710
1.21	0.734
1.46	0.747
1.68	0.755
1.71	0.754
1.74	0.760
1.99	0.761
2.13	0.753
2.32	0.752

TABLE 7-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

CURVE 16 (CONT.)

λ	ρ
2.36	0.740
2.44	0.695
2.52	0.674
2.59	0.672
2.65	0.677

CURVE 17
T = 293.

λ	ρ
0.230	0.526
0.236	0.492
0.252	0.450
0.261	0.452
0.288	0.462
0.308	0.453
0.324	0.455
0.330	0.458
0.360	0.456
0.527	0.511
0.627	0.566
0.679	0.585
0.700	0.581
0.712	0.599
0.847	0.654
1.03	0.700
1.28	0.724
1.45	0.726
1.83	0.736
1.92	0.733
2.03	0.734
2.17	0.727
2.33	0.723
2.38	0.707
2.48	0.650
2.60	0.641
2.65	0.650

CURVE 18
T = 293.

λ	ρ
0.230	0.526
0.236	0.492
0.252	0.450
0.261	0.452
0.288	0.462
0.308	0.453
0.325	0.453
0.374	0.452
0.530	0.492
0.612	0.532
0.679	0.556
0.704	0.552
0.713	0.572
0.853	0.620
0.992	0.651
1.13	0.669
1.24	0.675
1.75	0.680
2.01	0.677
2.07	0.668
2.25	0.665
2.34	0.656
2.39	0.637
2.46	0.599
2.53	0.579
2.59	0.574
2.65	0.580

CURVE 19
T = 293.

λ	ρ
0.230	0.526
0.243	0.462
0.255	0.442
0.264	0.439
0.284	0.443
0.297	0.434
0.302	0.435
0.305	0.429

CURVE 19 (CONT.)

λ	ρ
0.318	0.423
0.350	0.423
0.553	0.463
0.614	0.500
0.676	0.519
0.700	0.514
0.713	0.539
0.846	0.588
0.998	0.621
1.15	0.641
1.31	0.648
1.86	0.649
2.15	0.632
2.30	0.630
2.36	0.616
2.48	0.548
2.52	0.547
2.55	0.538
2.65	0.539

CURVE 20
T = 293.

λ	ρ
0.230	0.520
0.233	0.489
0.248	0.440
0.256	0.432
0.293	0.430
0.310	0.420
0.350	0.420
0.371	0.417
0.539	0.451
0.625	0.492
0.684	0.510
0.698	0.507
0.717	0.530
0.839	0.570
0.952	0.601
1.15	0.622
1.78	0.629

CURVE 20 (CONT.)

λ	ρ
1.93	0.620
2.02	0.620
2.15	0.609
2.27	0.604
2.36	0.591
2.47	0.534
2.55	0.519
2.65	0.521

CURVE 21
T = 293.

λ	ρ
0.230	0.488
0.232	0.442
0.241	0.400
0.259	0.371
0.270	0.367
0.297	0.362
0.310	0.359
0.340	0.356
0.345	0.359
0.350	0.356
0.364	0.346
0.534	0.391
0.617	0.441
0.681	0.469
0.696	0.468
0.704	0.481
0.820	0.537
0.967	0.584
1.11	0.608
1.29	0.619
1.55	0.621
1.79	0.619
2.02	0.613
2.15	0.601
2.29	0.600
2.37	0.578
2.41	0.550
2.51	0.518

CURVE 21 (CONT.)

λ	ρ
2.60	0.509
2.65	0.512

CURVE 22
T = 293.

λ	ρ
0.230	0.394
0.244	0.331
0.262	0.314
0.263	0.316
0.276	0.310
0.281	0.316
0.283	0.312
0.287	0.310
0.291	0.314
0.302	0.310
0.304	0.300
0.350	0.330
0.515	0.339
0.614	0.393
0.638	0.413
0.677	0.426
0.694	0.425
0.701	0.437
0.826	0.499
0.971	0.549
1.06	0.569
1.25	0.588
1.42	0.591
1.61	0.591
1.70	0.597
1.80	0.600
2.06	0.588
2.20	0.580
2.27	0.580
2.32	0.577
2.38	0.557
2.45	0.519
2.54	0.493
2.57	0.492

CURVE 22 (CONT.)

λ	ρ
2.60	0.488
2.53	0.489
2.65	0.486

CURVE 23
T = 293.

λ	ρ
2.00	0.698
2.12	0.706
2.18	0.698
2.54	0.439
2.62	0.254
2.68	0.240
2.75	0.240
3.00	0.294
3.04	0.290
3.11	0.200
3.13	0.158
3.24	0.139
3.50	0.103
5.93	0.103
6.04	0.118
6.10	0.155
6.19	0.376
6.26	0.410
6.48	0.465
6.74	0.537
7.00	0.582
7.19	0.591
7.26	0.567
7.42	0.397
7.64	0.298
7.76	0.280
7.99	0.258
8.20	0.246
8.60	0.242
9.01	0.214
9.40	0.206
10.2	0.216
10.9	0.207

TABLE 7-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 23(CONT.)	
11.3	0.215
11.7	0.236
11.9	0.249
12.0	0.249
12.1	0.228
12.1	0.184
12.2	0.178
12.5	0.215
13.0	0.239
15.0	0.245
CURVE 24	
T = 293.	
2.00	0.681
2.09	0.691
2.20	0.691
2.54	0.423
2.60	0.356
2.63	0.261
2.65	0.206
2.73	0.197
2.87	0.230
3.01	0.252
3.09	0.242
3.14	0.181
3.22	0.143
3.35	0.123
3.50	0.103
5.93	0.103
5.06	0.123
6.14	0.234
6.21	0.361
6.28	0.410
6.62	0.492
6.80	0.511
7.03	0.511
7.23	0.480
7.29	0.446
7.36	0.383

λ	ρ
CURVE 24(CONT.)	
7.44	0.336
7.68	0.271
7.82	0.243
8.00	0.225
8.54	0.220
8.92	0.199
9.62	0.191
9.80	0.196
11.2	0.203
11.5	0.210
11.9	0.250
12.0	0.250
12.1	0.226
12.1	0.191
12.1	0.169
12.2	0.166
12.6	0.207
13.0	0.228
15.0	0.234
CURVE 25	
T = 293.	
2.00	0.670
2.08	0.680
2.15	0.680
2.25	0.661
2.41	0.527
2.45	0.477
2.56	0.405
2.62	0.202
2.66	0.173
2.70	0.188
2.89	0.222
3.03	0.243
3.08	0.232
3.13	0.193
3.16	0.149
3.21	0.126
3.50	0.103

λ	ρ
CURVE 25(CONT.)	
5.93	0.103
6.08	0.118
6.13	0.147
6.18	0.306
6.28	0.335
6.46	0.337
6.72	0.377
6.98	0.389
7.22	0.389
7.29	0.379
7.39	0.303
7.45	0.280
7.62	0.244
7.79	0.221
8.00	0.208
8.59	0.211
8.79	0.195
9.06	0.179
9.50	0.175
10.3	0.188
10.8	0.186
11.5	0.201
11.8	0.231
12.0	0.231
12.1	0.217
12.1	0.166
12.2	0.166
12.6	0.199
CURVE 26	
T = 293.	
2.00	0.074
3.29	0.077
4.28	0.071
5.18	0.052
5.85	0.035
6.28	0.046
6.47	0.078
6.60	0.124

λ	ρ
CURVE 26(CONT.)	
6.72	0.395
6.94	0.437
7.17	0.446
7.44	0.448
7.81	0.260
7.99	0.223
8.31	0.189
8.70	0.167
9.33	0.146
10.0	0.130
10.6	0.114
12.0	0.060
12.4	0.075
12.6	0.108
12.6	0.143
12.7	0.165
13.3	0.169
15.2	0.128
15.7	0.088
16.2	0.077
16.9	0.071
17.3	0.073
19.3	0.093
21.4	0.122
22.4	0.139
23.5	0.143
24.5	0.142
28.0	0.118
33.7	0.101
34.6	0.093
35.2	0.082
35.9	0.064
CURVE 27	
T = 293.	
1.00	0.519
1.05	0.563
1.19	0.680
1.31	0.747

λ	ρ
CURVE 27(CONT.)	
1.36	0.777
1.42	0.791
1.51	0.800
1.60	0.800
1.71	0.795
1.80	0.788
1.88	0.772
1.99	0.751
2.05	0.723
2.10	0.667
2.14	0.580
2.17	0.550
2.22	0.470
2.28	0.397
2.35	0.323
2.43	0.269
2.52	0.224
2.68	0.166
2.86	0.127
3.00	0.106
3.19	0.089
3.34	0.078
3.49	0.072
3.80	0.072
4.00	0.076
4.28	0.074
4.67	0.062
4.92	0.062
5.00	0.058
5.50	0.046
5.99	0.031
6.09	0.040
6.16	0.056
6.20	0.091
6.29	0.325
6.51	0.504
6.60	0.569
6.71	0.638
6.82	0.694
6.92	0.722

λ	ρ
CURVE 27(CONT.)	
7.04	0.731
7.08	0.722
7.17	0.643
7.28	0.520
7.35	0.468
7.46	0.401
7.57	0.356
7.72	0.321
7.86	0.283
8.06	0.261
8.31	0.238
8.60	0.215
9.01	0.197
9.51	0.186
10.00	0.183
10.60	0.175
10.94	0.172
11.24	0.172
11.50	0.178
11.84	0.182
12.31	0.194
12.67	0.203
13.09	0.210
13.31	0.204
13.73	0.189
14.05	0.179
14.51	0.176
15.13	0.173
16.02	0.167
16.65	0.167
17.01	0.172
17.40	0.176
17.66	0.182
18.02	0.186
18.73	0.187
20.06	0.189
22.00	0.188
22.34	0.191
22.99	0.194
24.00	0.193

TABLE 7-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 28	
T = 293.	
0.29	0.589
0.29	0.493
0.35	0.477
0.41	0.605
0.47	0.811
0.50	0.828
0.50	0.862
0.66	0.891
0.86	0.891
1.05	0.876
1.26	0.860
1.41	0.855
1.61	0.842
1.70	0.815
1.91	0.790
2.01	0.770
2.11	0.741

d. Angular Spectral Reflectance (Wavelength Dependence)

A total of three sets of experimental data were located for the wavelength dependence of the angular spectral reflectance. The data are listed in Table 7-12 and shown in Figures 7-7 and 7-8. Specimen characterization and measurement information for the data are given in Table 7-11.

A provisional set of values, based on curve 2, is listed in Table 7-10 and shown in Figure 7-7. These room temperature values hold for a polished, 1/32 in. thick specimen of pyrolytic boron nitride manufactured by High Temperature Materials, Inc., with the angles θ and θ' both equal to 20°. An uncertainty of 30% or less is assigned.

TABLE 7-10. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ	λ	ρ	λ	ρ
PYROLYTIC,POLISH 0.79MM THICK T = 293		PYROLYTIC,POLISH 0.79MM THICK T = 293 (CONT.)		PYROLYTIC,POLISH 0.79MM THICK T = 293 (CONT.)	
3.0	0.101	6.6	0.352	10.2	0.155
3.1	0.092	6.7	0.424	10.3	0.153
3.2	0.085	6.8	0.496	10.4	0.151
3.3	0.080	6.9	0.574	10.5	0.150
3.4	0.076	6.95	0.620	10.6	0.148
3.5	0.073	6.98	0.631	10.7	0.147
3.6	0.071	7.0	0.635	10.8	0.145
3.7	0.069	7.04	0.630	10.9	0.143
3.8	0.067	7.1	0.595	11.0	0.142
3.9	0.066	7.2	0.540	11.1	0.140
4.0	0.065	7.3	0.490	11.2	0.139
4.1	0.064	7.4	0.444	11.3	0.137
4.2	0.063	7.5	0.404	11.4	0.136
4.3	0.062	7.6	0.364	11.5	0.134
4.4	0.061	7.7	0.332	11.6	0.132
4.5	0.060	7.8	0.302	11.7	0.131
4.6	0.059	7.9	0.277	11.8	0.129
4.7	0.058	8.0	0.256	11.9	0.128
4.8	0.056	8.1	0.240	12.0	0.126
4.9	0.055	8.2	0.226	12.1	0.124
5.0	0.054	8.3	0.214	12.2	0.123
5.1	0.052	8.4	0.204	12.3	0.120
5.2	0.050	8.5	0.196	12.4	0.122
5.3	0.048	8.6	0.190	12.5	0.126
5.4	0.044	8.7	0.184	12.6	0.135
5.5	0.041	8.8	0.180	12.7	0.148
5.6	0.037	8.9	0.177	12.8	0.159
5.7	0.032	9.0	0.176	12.9	0.169
5.8	0.026	9.1	0.174	13.0	0.175
5.85	0.023	9.2	0.172	13.1	0.180
5.90	0.022	9.3	0.170	13.2	0.184
9.93	0.021	9.4	0.168	13.3	0.185
5.98	0.027	9.5	0.167	13.4	0.186
6.0	0.032	9.6	0.165	13.5	0.184
6.1	0.074	9.7	0.163	13.6	0.182
6.2	0.122	9.8	0.162	13.7	0.177
6.3	0.172	9.9	0.160		
6.4	0.228	10.0	0.158		
6.5	0.288	10.1	0.156		

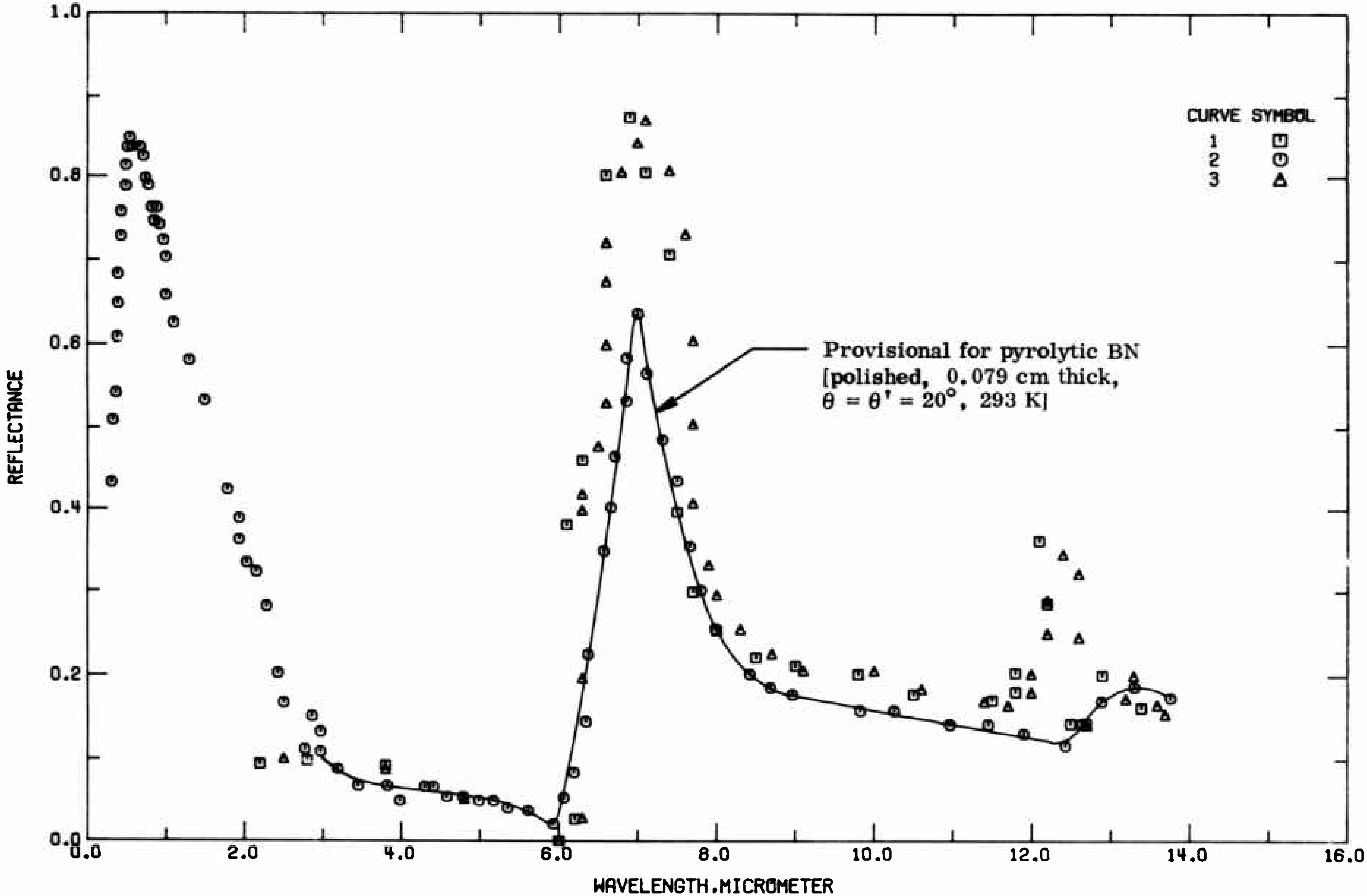


FIGURE 7-7. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE).

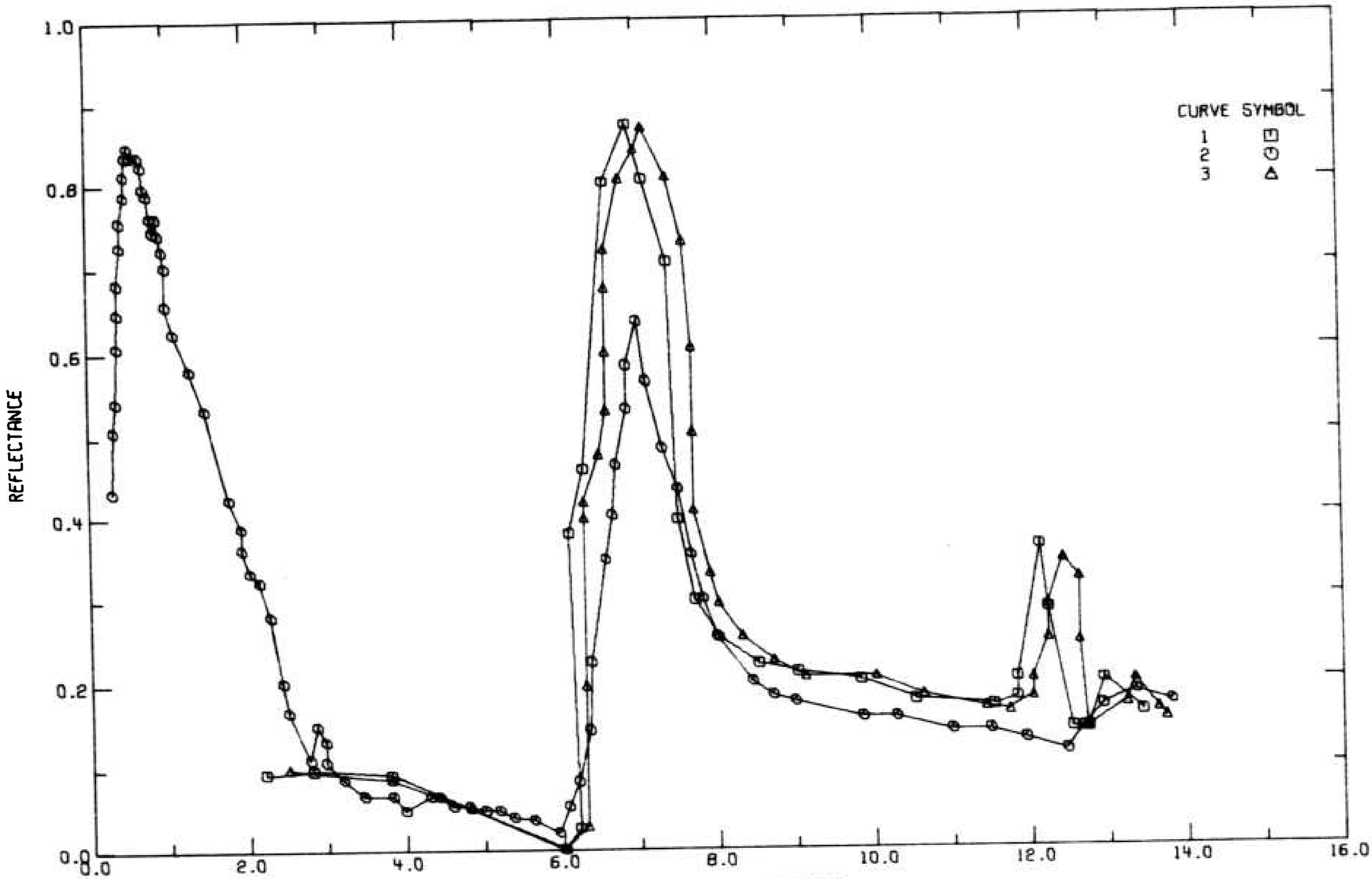


FIGURE 7-8. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE).

TABLE 7-11. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF BORON NITRIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T51145	McCarthy, D. E.	1968	2.2-50	293		Synthetic specimen; thickness 6.0 mm; flat to 10 fringes or better; reference standard aluminum mirror; commercial double-beam instrument used; temperature not explicitly given, assumed to be 293 K; smooth values from figure; θ=30°, θ'=30°.
2	T34724	Durand, S. L. and Houston, K. C.	1966	0.3-25	293	Pyrolytic	Specimen size about 2 x 3 x 0.5 in.; final dimensions 1 in. diameter, 1/32 in. thick; manufactured by High Temperature Materials, Inc., Lowell, Mass.; both surfaces ground to a finish of approx. 18 μ in.; AB surface (surface parallel to basal planes or planes of deposition) radiating; Gier Dunkle Reflectometer used; data from figure; specimen cemented to 1 in. diameter aluminum disk with 3M black low reflectivity paint which served as an opaque substrate; (no change in reflectivity from normal incidence to about 25° from normal); measurement temperature specified as room temperature, 293 K assigned; θ = 20°, θ' = 20°.
3	T40525	McCarthy, D. E.	1966	2.5-50	313		Polycrystalline specimen; thickness 6 mm; ground and polished to 5 fringes or better; smooth values from figure; θ = 30°, θ' = 30°.

TABLE 7-12. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
CURVE 1		CURVE 2		CURVE	2(CONT.)	CURVE	2(CONT.)	CURVE	3(CONT.)	CURVE	3(CONT.)
T = 293.		T = 293.									
				3.19	0.088	13.31	0.186	7.1	0.869	38.1	0.153
2.20	0.094	0.30	0.432	3.45	0.068	13.77	0.173	7.4	0.806	40.1	0.153
2.80	0.098	0.32	0.508	3.82	0.068	16.58	0.174	7.6	0.730	41.1	0.151
3.80	0.092	0.36	0.542	3.98	0.050	17.21	0.181	7.7	0.604	42.0	0.151
6.00	0.000	0.38	0.607	4.30	0.067	17.68	0.194	7.7	0.504	43.2	0.154
6.20	0.027	0.39	0.647	4.41	0.067	18.08	0.205	7.7	0.407	44.2	0.154
6.10	0.379	0.39	0.682	4.58	0.055	18.40	0.205	7.9	0.331	45.5	0.154
6.30	0.459	0.43	0.727	4.79	0.055	18.85	0.199	8.0	0.295	45.8	0.154
6.60	0.800	0.43	0.756	4.99	0.050	19.43	0.228	8.3	0.255	46.9	0.154
6.90	0.872	0.49	0.787	5.17	0.050	19.97	0.202	8.7	0.226	48.1	0.154
7.10	0.803	0.49	0.812	5.35	0.041	20.40	0.223	9.1	0.206	50.0	0.154
7.40	0.705	0.51	0.834	5.61	0.038	20.99	0.213	10.0	0.206		
7.50	0.395	0.54	0.847	5.93	0.021	21.47	0.220	10.6	0.184		
7.70	0.298	0.57	0.835	6.06	0.054	21.99	0.220	11.4	0.169		
8.00	0.253	0.67	0.835	6.19	0.084	22.38	0.230	11.7	0.164		
8.50	0.221	0.71	0.823	6.34	0.145	22.69	0.230	12.0	0.180		
9.00	0.211	0.74	0.796	6.37	0.225	23.14	0.220	12.0	0.202		
9.80	0.201	0.78	0.788	6.57	0.347	23.65	0.222	12.2	0.250		
10.5	0.177	0.82	0.761	6.66	0.401	24.01	0.209	12.2	0.289		
11.5	0.170	0.85	0.745	6.71	0.464	24.38	0.219	12.4	0.344		
11.8	0.180	0.89	0.761	6.86	0.532	25.00	0.235	12.6	0.321		
11.8	0.203	0.92	0.741	6.86	0.583			12.6	0.246		
12.1	0.360	0.97	0.722	7.00	0.635	CURVE 3		12.7	0.142		
12.2	0.285	1.00	0.702	7.11	0.565	T = 313.		13.2	0.172		
12.5	0.143	1.00	0.657	7.31	0.485			13.3	0.200		
12.7	0.143	1.10	0.624	7.50	0.434	2.5	0.101	13.6	0.165		
12.9	0.200	1.30	0.580	7.66	0.353	3.8	0.088	13.7	0.154		
13.4	0.161	1.49	0.533	7.80	0.300	4.8	0.053	15.0	0.154		
14.9	0.154	1.78	0.423	7.98	0.255	6.0	0.000	17.3	0.158		
22.7	0.172	1.93	0.387	8.42	0.201	6.3	0.029	20.0	0.167		
25.3	0.190	1.93	0.361	8.68	0.185	6.3	0.197	22.2	0.172		
26.5	0.190	2.03	0.333	8.95	0.177	6.3	0.398	25.0	0.187		
28.2	0.168	2.15	0.322	9.82	0.158	6.3	0.418	26.3	0.187		
29.7	0.143	2.28	0.281	10.25	0.158	6.5	0.477	28.3	0.167		
31.7	0.132	2.43	0.202	10.96	0.142	6.6	0.530	30.1	0.137		
35.0	0.154	2.50	0.167	11.45	0.142	6.6	0.599	30.8	0.134		
50.0	0.156	2.77	0.112	11.90	0.131	6.6	0.674	31.6	0.133		
		2.86	0.151	12.43	0.117	6.6	0.720	33.4	0.142		
		2.97	0.133	12.64	0.143	6.8	0.804	35.0	0.154		
		2.97	0.109	12.89	0.169	7.0	0.840	37.1	0.150		

e. Normal Spectral Transmittance (Wavelength Dependence)

A total of seven sets of experimental data were located for the wavelength dependence of the normal spectral transmittance of boron nitride. The data are listed in Table 7-15 and shown in Figures 7-9 and 7-10. Specimen characterization and measurement information for the data are given in Table 7-14.

For the purposes of this report, the first four data sets are useless in aiding to arrive at evaluated data. Curve 5 forms the basis of a typical set of values which are valid at room temperature for platelets of yellow, undoped, single-crystals of cubic boron nitride. An assignment of typical is necessitated because of uninformed specimen dimensions. The uncertainty assigned is 30% or more.

TABLE 7-13. TYPICAL NORMAL SPECTRAL TRANSMITTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CUBIC,UNDOPED YELLOW T = 293		CUBIC,UNDOPED YELLOW T = 293 (CONT.)		CUBIC,UNDOPED YELLOW T = 293 (CONT.)		CUBIC,UNDOPED YELLOW T = 293 (CONT.)		CUBIC,UNDOPED YELLOW T = 293 (CONT.)	
0.20	0.000	2.0	0.739	5.43	0.253	9.0	0.000	12.9	0.565
0.24	0.014	2.1	0.738	5.47	0.191	9.1	0.000	13.0	0.567
0.26	0.030	2.2	0.738	5.50	0.206	9.2	0.000		
0.28	0.040	2.3	0.733	5.55	0.236	9.3	0.000		
0.30	0.053	2.4	0.738	5.6	0.256	9.4	0.000		
0.31	0.058	2.5	0.738	5.7	0.284	9.5	0.000		
0.33	0.079	2.6	0.738	5.8	0.304	9.6	0.000		
0.36	0.108	2.7	0.738	5.9	0.319	9.7	0.000		
0.38	0.132	2.8	0.738	6.0	0.322	9.8	0.000		
0.40	0.156	2.9	0.738	6.1	0.344	9.9	0.000		
0.41	0.169	3.0	0.739	6.2	0.356	10.0	0.000		
0.44	0.203	3.1	0.738	6.3	0.367	10.1	0.056		
0.48	0.256	3.2	0.738	6.4	0.378	10.2	0.102		
0.50	0.303	3.3	0.738	6.5	0.389	10.3	0.146		
0.53	0.352	3.4	0.738	6.6	0.399	10.4	0.186		
0.57	0.414	3.5	0.738	6.7	0.410	10.5	0.226		
0.60	0.470	3.6	0.738	6.8	0.416	10.6	0.252		
0.61	0.489	3.7	0.738	6.9	0.415	10.7	0.293		
0.63	0.543	3.8	0.738	7.0	0.407	10.8	0.326		
0.65	0.585	3.9	0.737	7.1	0.374	10.9	0.354		
0.68	0.620	4.0	0.735	7.2	0.318	11.0	0.380		
0.70	0.651	4.1	0.733	7.3	0.256	11.1	0.403		
0.72	0.680	4.15	0.730	7.4	0.174	11.2	0.427		
0.74	0.693	4.20	0.726	7.5	0.076	11.3	0.449		
0.77	0.717	4.25	0.722	7.6	0.016	11.4	0.467		
0.80	0.726	4.30	0.714	7.63	0.000	11.5	0.483		
0.803	0.736	4.4	0.675	7.7	0.000	11.6	0.496		
0.806	0.7375	4.5	0.624	7.8	0.000	11.7	0.508		
0.90	0.738	4.6	0.555	7.9	0.000	11.8	0.517		
1.0	0.739	4.7	0.491	8.0	0.000	11.9	0.526		
1.1	0.739	4.8	0.414	8.1	0.000	12.0	0.533		
1.2	0.738	4.9	0.306	8.2	0.000	12.1	0.540		
1.3	0.738	5.0	0.181	8.3	0.000	12.2	0.545		
1.4	0.738	5.04	0.182	8.4	0.000	12.3	0.553		
1.5	0.738	5.1	0.184	8.5	0.000	12.4	0.554		
1.6	0.738	5.2	0.191	8.6	0.000	12.5	0.557		
1.7	0.738	5.3	0.204	8.7	0.000	12.6	0.560		
1.8	0.739	5.35	0.216	8.8	0.000	12.7	0.562		
1.9	0.738	5.40	0.232	8.9	0.000	12.8	0.563		

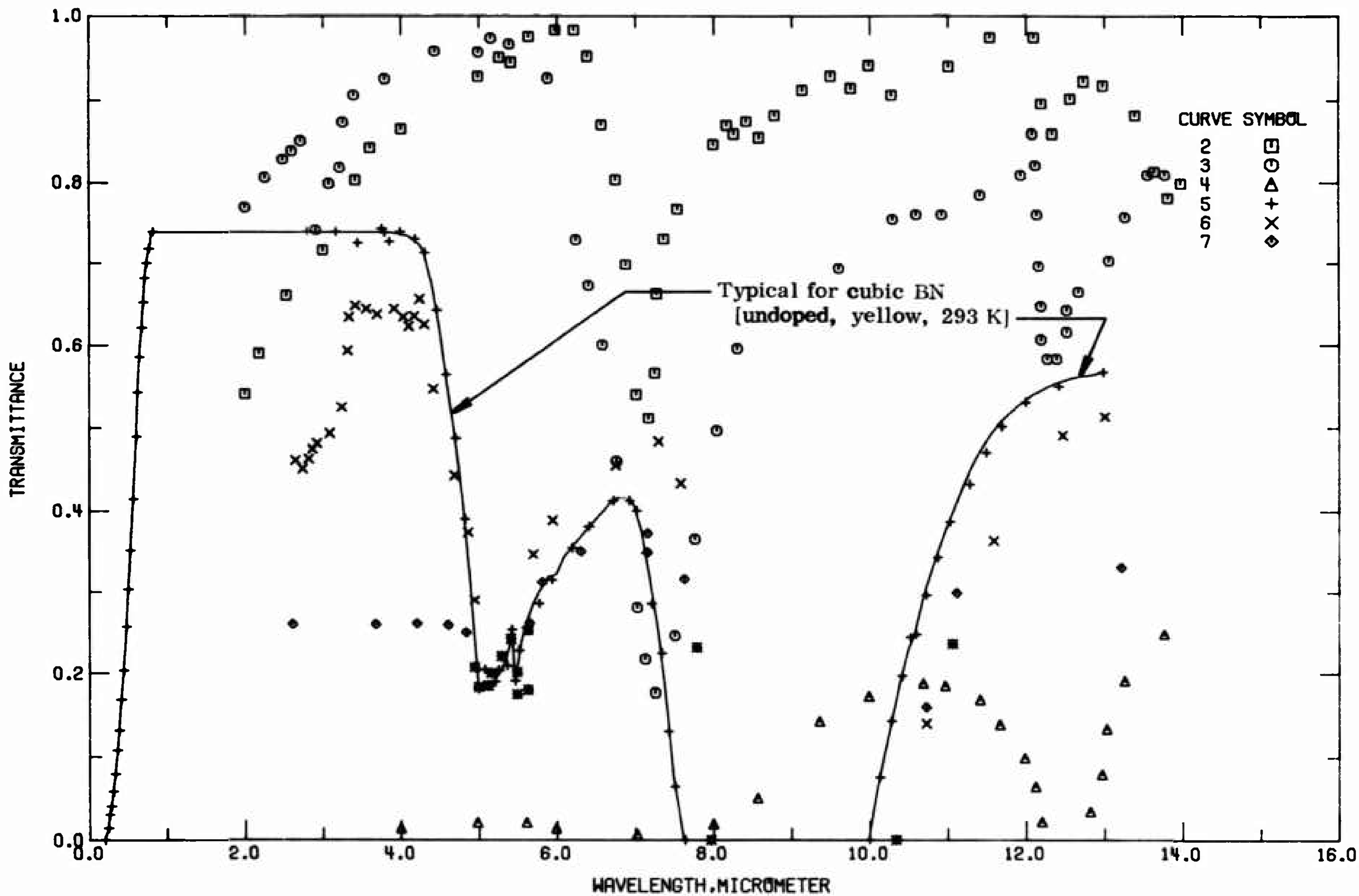


FIGURE 7-9. TYPICAL NORMAL SPECTRAL TRANSMITTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE).

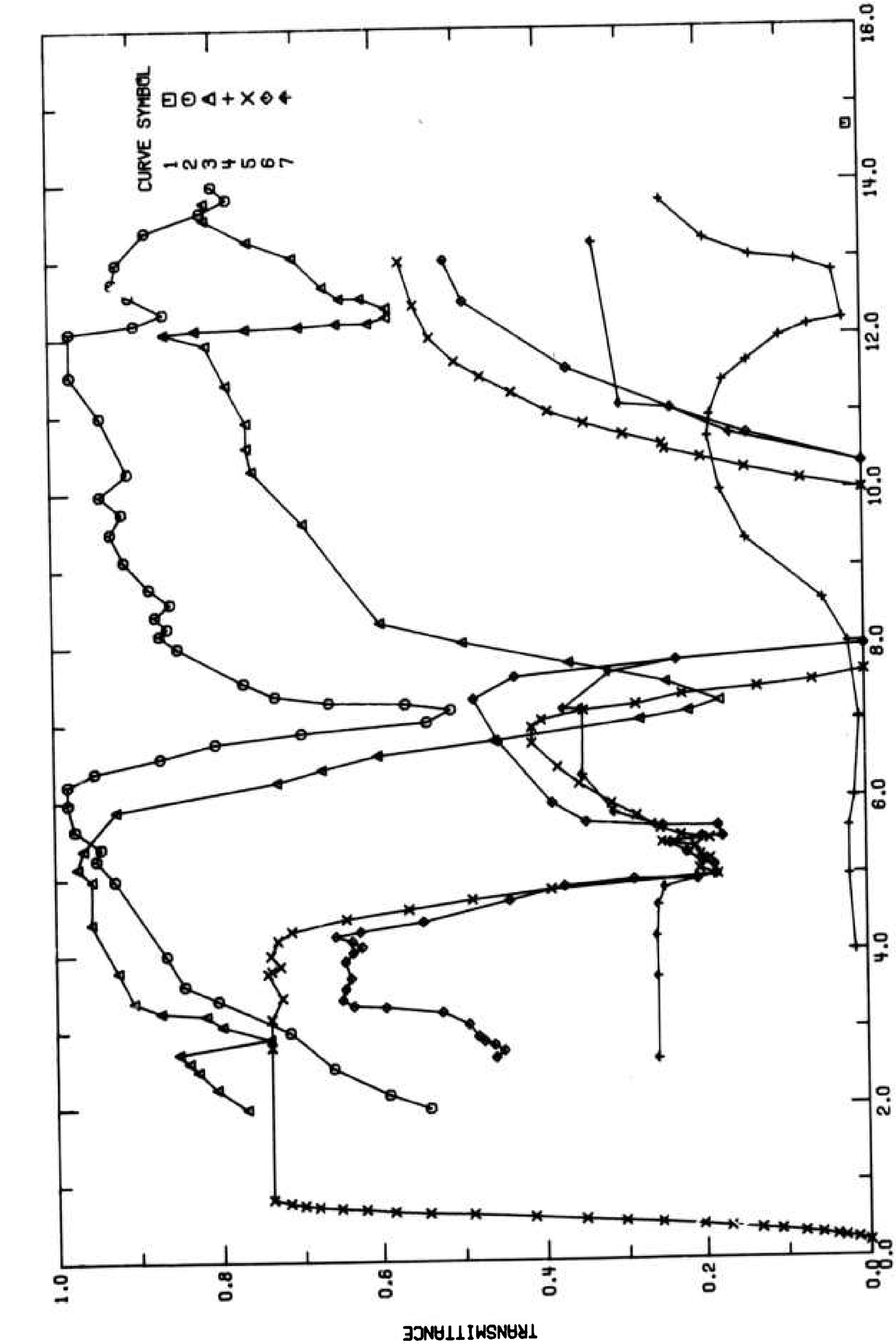


FIGURE 7-10. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE).

TABLE 7-14. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF BORON NITRIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T51145	McCarthy, D.E.	1968	15-50	293		Synthetic specimen; thickness 6.0 mm; flat to 10 fringes or better, reference standard aluminum mirror; commercial double-beam instrument used; temperature not explicitly given, presumed to be 293 K; smooth values from figure; $\theta = 0°$, $\theta' = 0°$.
2	T58818	Miller, F.A. and Wilkins, C.H.	1952	2.0-16	293		Pure; fine powder suspended in Nujol; measurements made with Baird Model A spectrophotometer; smooth values from figure; wavelength measurements accurate to approx. ±0.03 μ; portion of spectra from 2 to just over 7 μm run in fluorolube; dip in spectra just below 14 μm a Nujol band; measurement temperature not given explicitly, assumed to be 293 K.
3	T60470	Brame, E.G., Jr., Margrave, J.L., and Meloche, V.W.	1957	2-16	293		Hexagonal crystal structure; disk 1 mm thick and 12 mm in diameter; Baird Associates Model B spectrophotometer used; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K.
4	T29708	Redfield, D. and Baum, R.L.	1961	4-15	293		1 mg BN in 300 mg KRS-5 pressed at 270 000 psi to an 0.375 in diameter and 0.025 in thickness; smooth values from figure.
5	A00014	DeVries, R.C.	1972	0.2-13	293		Single-crystal (yellow, undoped); data taken on assemblage of small hexagonal-shaped platelets of cubic BN; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K.
6	T42872	Gielisse, P.J., Mitra, S.S., Plendl, J.N., Griffis, R.D., Mansur, L.C., Marshall, R., and Pascoe, E.A.	1967	2.7-24	293		Single crystal platelets with cubic structure (30 μm thick); grown at very high pressure and temperature; 10^{10} Ω cm electrical resistivity; smooth values from figure; percent absorption reported on figure, normal spectral transmittance arrived at by equating percent normal spectral transmittance to 1.0 minus percent absorption.
7	T42872	Gielisse, P.J., et al.	1967	2.6-27	293		Similar to the above specimen except beryllium doped.

TABLE 7-15. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ
CURVE 1	
T = 293.	
14.7	0.013
24.4	0.043
29.6	0.076
30.7	0.062
32.9	0.069
35.4	0.095
44.6	0.103
49.6	0.103
49.9	0.103
CURVE 2	
T = 293.	
2.00	0.541
2.18	0.590
2.53	0.659
3.00	0.715
3.42	0.802
3.61	0.842
4.01	0.864
5.00	0.927
5.27	0.949
5.42	0.943
5.65	0.374
5.99	0.982
6.23	0.982
6.40	0.950
6.58	0.869
6.76	0.802
6.89	0.697
7.02	0.540
7.18	0.511
7.26	0.566
7.28	0.661
7.37	0.729
7.55	0.767
8.01	0.846
8.18	0.868
8.27	0.858

λ	τ
CURVE 2 (CONT.)	
8.43	0.873
8.59	0.854
8.79	0.880
9.15	0.911
9.51	0.927
9.77	0.913
10.00	0.939
10.29	0.905
11.02	0.938
11.55	0.973
12.11	0.973
12.21	0.895
12.35	0.858
12.58	0.901
12.75	0.921
13.00	0.916
13.41	0.880
13.66	0.812
13.83	0.780
14.00	0.798
14.14	0.818
14.40	0.816
14.73	0.780
15.00	0.739
15.49	0.702
15.66	0.691
15.82	0.683
16.00	0.687
CURVE 3	
T = 293.	
2.00	0.769
2.26	0.805
2.49	0.827
2.60	0.838
2.72	0.850
2.91	0.740
3.08	0.798
3.22	0.817

λ	τ
CURVE 3 (CONT.)	
3.25	0.872
3.40	0.905
3.90	0.924
4.44	0.956
5.00	0.955
5.16	0.972
5.40	0.965
5.89	0.925
6.25	0.728
6.41	0.671
6.59	0.600
6.77	0.459
7.03	0.280
7.13	0.217
7.26	0.177
7.51	0.245
7.77	0.366
8.05	0.496
8.31	0.595
9.61	0.692
10.33	0.754
10.60	0.760
10.93	0.760
11.42	0.784
11.94	0.808
12.09	0.858
12.13	0.820
12.15	0.760
12.17	0.695
12.20	0.646
12.20	0.606
12.28	0.583
12.40	0.583
12.53	0.615
12.53	0.641
12.68	0.663
13.07	0.702
13.29	0.757
13.57	0.808
13.79	0.808

λ	τ
CURVE 3 (CONT.)	
14.19	0.840
14.42	0.850
14.68	0.844
14.96	0.829
15.41	0.813
15.47	0.791
15.63	0.791
15.63	0.773
15.87	0.767
16.00	0.728
CURVE 4	
T = 293.	
4.00	0.014
4.98	0.021
5.61	0.021
5.99	0.014
7.02	0.007
8.00	0.019
8.57	0.050
9.36	0.143
9.99	0.173
10.69	0.188
10.97	0.185
11.42	0.169
11.67	0.139
11.99	0.099
12.13	0.064
12.21	0.022
12.83	0.034
12.98	0.079
13.04	0.134
13.27	0.191
13.78	0.247
14.25	0.266
14.58	0.269
15.00	0.262

λ	τ
CURVE 5	
T = 293.	
0.20	0.000
0.24	0.014
0.26	0.030
0.28	0.040
0.31	0.058
0.33	0.079
0.36	0.108
0.38	0.132
0.41	0.169
0.44	0.203
0.48	0.256
0.50	0.303
0.53	0.352
0.57	0.414
0.61	0.489
0.63	0.543
0.65	0.585
0.68	0.620
0.70	0.651
0.72	0.680
0.74	0.699
0.77	0.717
0.82	0.738
2.80	0.738
3.17	0.738
3.45	0.724
3.76	0.742
3.80	0.737
3.86	0.726
4.00	0.738
4.19	0.729
4.31	0.712
4.47	0.641
4.59	0.564
4.71	0.487
4.83	0.390
5.00	0.181
5.08	0.204
5.21	0.190

λ	τ
CURVE 5 (CONT.)	
5.26	0.203
5.37	0.209
5.43	0.253
5.47	0.191
5.52	0.227
5.61	0.255
5.78	0.285
5.94	0.315
6.20	0.355
6.42	0.381
6.73	0.412
6.94	0.412
7.03	0.400
7.15	0.349
7.22	0.285
7.35	0.224
7.43	0.131
7.51	0.064
7.63	0.000
10.00	0.000
10.13	0.075
10.28	0.143
10.42	0.197
10.53	0.243
10.60	0.247
10.73	0.296
10.88	0.344
11.04	0.387
11.29	0.432
11.50	0.470
11.70	0.501
12.01	0.531
12.43	0.550
13.00	0.567
CURVE 6	
T = 293.	
2.65	0.460
2.74	0.450

TABLE 7-15. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF BORON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ
CURVE	6(CONT.)
2.82	0.462
2.87	0.474
2.93	0.481
3.09	0.493
3.25	0.525
3.32	0.593
3.34	0.633
3.42	0.647
3.56	0.643
3.70	0.635
3.92	0.643
4.037	0.633
4.107	0.622
4.177	0.634
4.246	0.655
4.307	0.624
4.429	0.547
4.695	0.442
4.873	0.374
4.951	0.289
4.948	0.207
5.005	0.183
5.123	0.185
5.160	0.200
5.294	0.220
5.414	0.241
5.492	0.201
5.492	0.175
5.634	0.180
5.640	0.251
5.705	0.347
5.952	0.388
6.761	0.454
7.310	0.483
7.593	0.433
7.794	0.231
7.968	0.000
10.34	0.000
10.73	0.140
11.07	0.235

λ	τ
CURVE	6(CONT.)
11.60	0.364
12.48	0.490
13.02	0.513
14.06	0.505
14.84	0.536
15.38	0.512
16.42	0.491
17.61	0.506
17.86	0.660
24.27	0.774

CURVE 7
T = 293.

λ	τ
2.61	0.259
3.68	0.259
4.21	0.260
4.61	0.258
4.84	0.249
4.95	0.207
5.00	0.183
5.123	0.185
5.160	0.200
5.294	0.220
5.414	0.241
5.492	0.201
5.492	0.175
5.634	0.180
5.640	0.251
5.653	0.261
5.817	0.312
6.309	0.351
7.163	0.350
7.169	0.373
7.639	0.316
7.794	0.231
7.968	0.000
10.34	0.000
13.73	0.160
11.07	0.235

λ	τ
CURVE	7(CONT.)
11.12	0.299
13.23	0.331
17.33	0.349
25.88	0.364

4.8. Calcium Aluminum Silicate

Since data evaluation was asked to be carried out on the specific kind of calcium aluminum silicate known as Corning 9753, the treatment in this section will concentrate on that material.

Corning 9753 is a solid solution of 30% CaO, 40% Al_2O_3, and 30% SiO_2 and is an infrared transmitting glass. It is a product of the Corning Glass Works, Corning, New York 14830. Other names by which it is known include Corning Code 9753, glass 9753, CGW-Glass 9753, Corning 9753 glass, and Cortran Code 9753. Cortran is a secondary trademark of the Corning Glass Works.

This material has several interesting physical properties which lead to its suitability for airborne applications. It melts around 1723 to 1773 K [T28664]. According to the Corning Glass Works specification sheet for Code 9753, copyrighted in 1970, other physical properties are as follows: It has a softening point (extrapolated) of 1254K, an annealing point of 1105 K, and a strain point of 1073K. The linear expansion coefficient between 298 and 573 K is 59.5×10^{-7} C^{-1} while between 29.8 and 973 K it is 72×10^{-7} C^{-1}. Code 9753 has a density of 2.798 g cm^{-3}, a Young's modulus of 14.3×10^6 psi, a shear modulus of 5.6×10^6 psi, and a Poisson's ratio of 0.28. The Knoop hardness is 657.5 for a 100 g load and 601 for a 500 g load. These values of hardness makes this material highly suitable for high-speed airborne applications and coupled with its infrared transmitting properties leads to its use on heat-seeking missiles. The refractive index at 0.4867 μm is 1.61251, at 0.5893 μm is 1.60475, and at 0.6563 μm is 1.60151. The dielectric constant at 1 Mc and 298 K is 8.87 while for the same frequency it is 9.51 at 773 K; it is 8.28 at 298 K, 8.59 at 573 K, 8.66 at 673 K, and 8.76 at 773 K, all at 8600 Mc. The loss tangent at 1 Mc and 298 K is 0.0025 while for the same frequency it is 0.0029 at 773 K; it is 0.011 at 298 K, 0.01 at 573 K, 0.01 at 673 K, and 0.01 at 773 K, all at 8600 Mc. The log of the dc resistivity (ohm-cm) is 18.0 at 523 K, 15.0 at 623 K, and 11.8 at 773 K.

a. Normal Spectral Emittance (Wavelength Dependence)

There are six sets of experimental data available for the wavelength dependence of the normal spectral emittance, $\epsilon(\theta' \approx 0°)$, of calcium aluminum silicate all of which apply to Corning 9753. The data is listed in Table 8-3 and shown in Figures 8-1 and 8-2. Specimen characterization and measurement information for the data are given in Table 8-2. Three data sets are for a specimen 0.3175 cm thick measured at temperatures 473 to 873 K. The remaining three data sets are for a 1.27 cm thick specimen covering the same temperature range.

It is observed that each of the six data sets is for a different combination of thickness and temperature and hence there is no direct confirmatory evidence for an individual data set. As a consequence of this lack of confirmatory evidence, only provisional values are justified. Two provisional curves are given for Corning 9753 for a specimen of 0.3175 cm with one curve applicable to 473 K and the other curve to 873 K. The provisional values are listed in Table 8-1 and shown in Figure 8-1. The thickness of 0.3175 cm is selected so as to be close to a thickness of 0.2 to 0.4 cm which is often used in reporting measurements. These two provisional curves are the same as curves 1 and 3 in Table 8-3 and Figure 8-1 with additional values reported. The uncertainty for the provisional values is within 30%.

It is noted that for curves 1-6 in Tables 8-2 and 8-3, data is not available for wavelengths below 1.5 μm and above 8.0 μm. In addition, data is unavailable over the entire wavelength region for temperatures above 873 K.

Assuming that the normal spectral emittance above 8.0 μm continues at a high and roughly constant value, the magnitude of emittance will be about 0.8 for a 3.175 mm thick specimen from 473 to 873 K.

Corroborating evidence of a high and roughly constant value above 8 μm for a slightly different thickness comes from the provisional values at 293 K for a specimen of 2 mm thick. These values are listed in Table 8-1 and shown in Figure 8-1. They were generated by using Eq. (2.3-2) to find α and using Kirchhoff's law, Eq. (2.3-4), to find the normal spectral emittance. The values of the normal spectral transmittance used in Eq. (2.3-2) are the provisional values listed in Table 8-12 and shown in Figure 8-9; these values apply to a temperature of 293 K and a specimen thickness of 2 mm. From 5.0 to 15 μm it was assumed the transmittance was zero. The values of the normal spectral reflectance used in Eq. (2.3-2) are the provisional values listed in Table 8-5 and shown in Figure 8-4; these values apply to a temperature of 293 K and a thickness of 1.99 mm. The uncertainty is thought to be well within 30% over most of the wavelength region.

TABLE 8-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF CALCIUM ALUMINUM SILICATE (CORNING 9753) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
2.00MM THICK	
T = 293	
0.40	0.101
0.50	0.029
0.60	0.017
0.80	0.015
0.90	0.020
1.00	0.024
1.10	0.026
1.20	0.027
1.30	0.028
1.40	0.028
1.50	0.028
1.60	0.027
1.70	0.027
1.80	0.026
2.00	0.026
2.30	0.025
2.40	0.026
2.50	0.027
2.60	0.031
2.70	0.036
2.80	0.043
2.90	0.062
3.20	0.066
3.30	0.064
3.40	0.064
3.50	0.064
3.80	0.086
3.90	0.100
4.00	0.118
4.10	0.151
4.20	0.202
4.30	0.272
4.40	0.391
4.50	0.543
4.60	0.715
4.70	0.824
4.80	0.900
4.90	0.944
5.00	0.965

λ	ε
2.00MM THICK	
T = 293 (CONT.)	
5.10	0.966
5.20	0.966
5.30	0.967
5.40	0.967
5.50	0.968
5.60	0.968
5.70	0.969
5.80	0.969
5.90	0.970
6.00	0.970
6.10	0.971
6.20	0.971
6.30	0.972
6.40	0.973
6.50	0.974
6.60	0.975
6.70	0.976
6.80	0.977
6.90	0.978
7.00	0.979
7.10	0.980
7.20	0.981
7.30	0.982
7.40	0.983
7.50	0.984
7.60	0.986
7.70	0.987
7.80	0.989
7.90	0.990
8.00	0.996
8.10	1.00
8.20	1.00
8.30	1.00
8.40	1.00
8.50	1.00
8.60	1.00
8.70	0.998
8.80	0.993
8.90	0.992

λ	ε
2.00MM THICK	
T = 293 (CONT.)	
9.00	0.973
9.10	0.965
9.20	0.954
9.30	0.934
9.40	0.902
9.50	0.886
9.60	0.873
9.70	0.864
9.80	0.856
9.90	0.848
10.0	0.841
10.1	0.832
10.2	0.825
10.3	0.825
10.4	0.820
10.5	0.820
10.6	0.820
10.7	0.821
10.8	0.822
10.9	0.823
11.0	0.826
11.1	0.837
11.2	0.839
11.3	0.844
11.4	0.849
11.5	0.855
11.6	0.860
11.7	0.866
11.8	0.871
11.9	0.876
12.0	0.880
12.1	0.885
12.2	0.890
12.3	0.897
12.4	0.905
12.5	0.910
12.6	0.914
12.7	0.916
12.8	0.916

λ	ε
2.00MM THICK	
T = 293 (CONT.)	
12.9	0.916
13.0	0.915
13.1	0.915
13.2	0.915
13.3	0.915
13.4	0.916
13.5	0.915
13.6	0.914
13.7	0.912
13.8	0.910
13.9	0.909
14.0	0.905
14.1	0.901
14.2	0.895
14.3	0.890
14.4	0.885
14.5	0.882
14.6	0.879
14.7	0.877
14.8	0.873
14.9	0.866

λ	ε
3.175MM THICK	
T = 473	
2.40	0.110
2.47	0.103
2.50	0.099
2.59	0.090
2.60	0.089
2.70	0.080
2.73	0.077
2.80	0.070
2.81	0.069
2.90	0.065
2.91	0.065
3.0	0.061
3.04	0.060
3.10	0.059
3.20	0.060
3.21	0.060
3.30	0.064
3.31	0.065
3.40	0.073
3.46	0.079
3.50	0.084
3.57	0.095
3.60	0.101
3.70	0.122
3.80	0.144
3.90	0.167
4.00	0.190
4.02	0.195
4.09	0.227
4.10	0.229
4.18	0.278
4.20	0.294
4.24	0.332
4.30	0.383
4.38	0.453
4.40	0.469
4.46	0.534
4.50	0.580
4.58	0.648

λ	ε
3.175MM THICK	
T = 473 (CONT.)	
4.60	0.676
4.64	0.700
4.70	0.758
4.71	0.775
4.74	0.805
4.77	0.823
4.80	0.832
4.82	0.841
4.87	0.854
4.90	0.858
4.91	0.860
4.96	0.869
5.00	0.870
5.08	0.869
5.10	0.868
5.20	0.862
5.22	0.860
5.30	0.851
5.40	0.840
5.42	0.838
5.50	0.832
5.53	0.828
5.60	0.823
5.65	0.820
5.70	0.818
5.76	0.820
5.80	0.822
5.85	0.824
5.90	0.828
5.98	0.835
6.00	0.837
6.18	0.858
6.10	0.849
6.20	0.860
6.29	0.869
6.30	0.870
6.38	0.876
6.40	0.877
6.43	0.879

TABLE 8-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF CALCIUM ALUMINUM SILICATE (CORNING 9753) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

3.175MM THICK

T = 473 (CONT.)

λ	ε
6.50	0.880
6.53	0.879
6.60	0.874
6.64	0.871
6.70	0.862
6.76	0.852
6.80	0.845
6.86	0.833
6.90	0.826
6.97	0.818
7.00	0.817
7.09	0.818
7.10	0.818
7.18	0.820
7.20	0.822
7.30	0.828
7.40	0.834
7.42	0.835
7.50	0.837
7.59	0.835
7.60	0.835
7.68	0.831
7.70	0.830
7.80	0.826
7.84	0.822
7.90	0.819
8.00	0.811

3.175MM THICK

T = 873

λ	ε
1.52	0.043
1.60	0.041
1.70	0.037
1.80	0.034
1.88	0.032
1.90	0.031
2.00	0.030
2.10	0.028
2.19	0.028
2.20	0.028
2.30	0.031
2.34	0.032
2.40	0.035
2.50	0.040
2.59	0.045
2.60	0.046
2.70	0.051
2.76	0.053
2.80	0.056
2.90	0.066
2.99	0.073
3.00	0.074
3.10	0.082
3.20	0.090
3.26	0.096
3.30	0.099
3.40	0.111
3.44	0.116
3.50	0.124
3.56	0.133
3.60	0.140
3.69	0.159
3.70	0.163
3.80	0.196
3.82	0.204
3.90	0.232
3.99	0.267
4.00	0.273
4.08	0.317

3.175MM THICK

T = 873 (CONT.)

λ	ε
4.10	0.328
4.26	0.446
4.20	0.402
4.30	0.480
4.40	0.565
4.48	0.635
4.50	0.640
4.60	0.702
4.63	0.721
4.70	0.783
4.75	0.807
4.80	0.819
4.82	0.827
4.90	0.846
4.91	0.848
4.99	0.860
5.00	0.861
5.09	0.869
5.10	0.870
5.20	0.876
5.30	0.878
5.36	0.878
5.40	0.879
5.50	0.880
5.55	0.878
5.60	0.878
5.67	0.875
5.70	0.873
5.80	0.866
5.90	0.860
5.99	0.855
6.00	0.854
6.10	0.847
6.12	0.846
6.20	0.842
6.30	0.839
6.32	0.839
6.40	0.836
6.50	0.834

3.175MM THICK

T = 873 (CONT.)

λ	ε
6.57	0.832
6.60	0.832
6.70	0.832
6.80	0.832
6.90	0.833
7.00	0.833
7.10	0.833
7.20	0.833
7.30	0.832
7.40	0.831
7.50	0.830
7.60	0.832
7.70	0.835
7.80	0.837
7.90	0.839
8.00	0.842

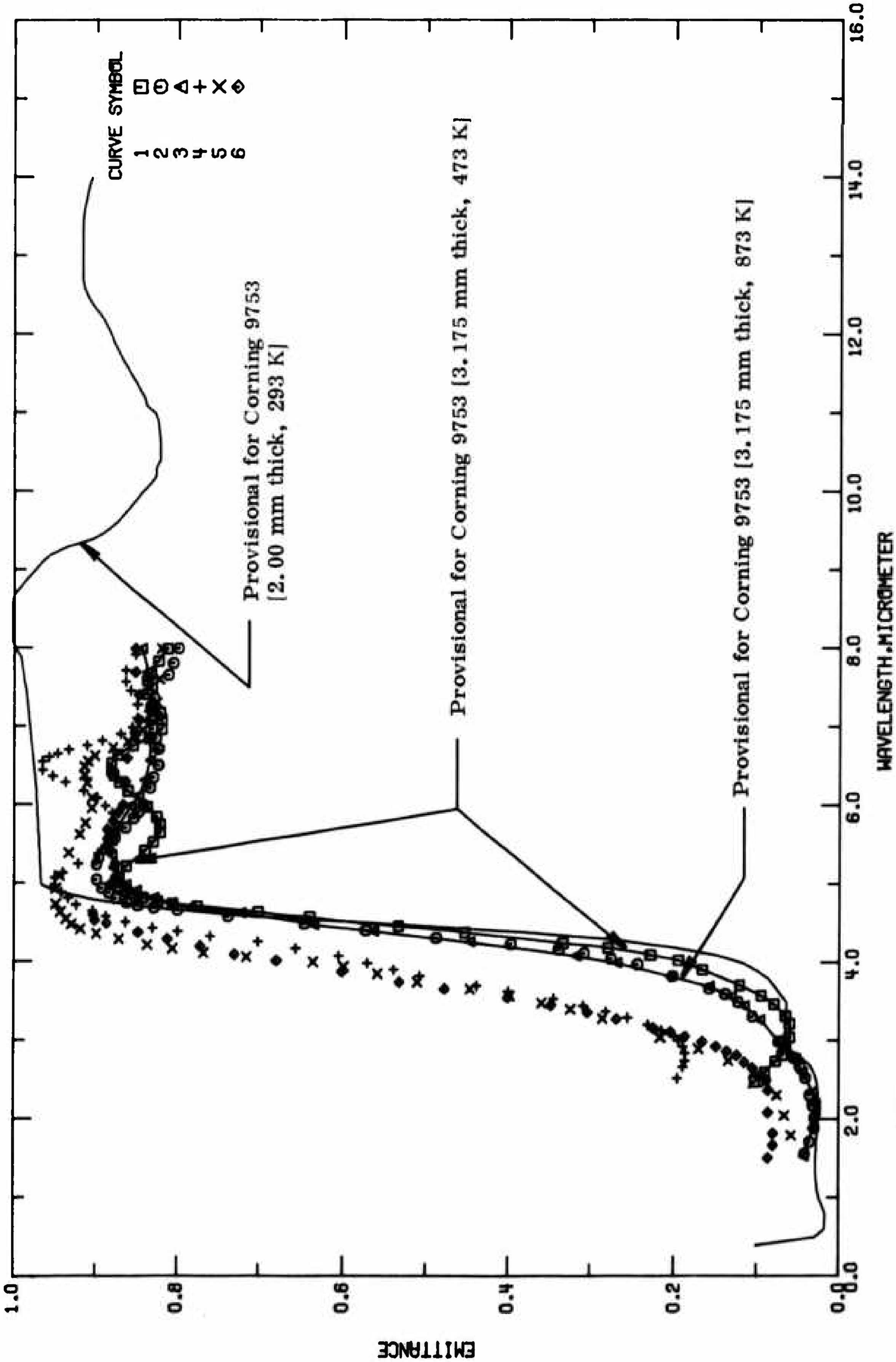


FIGURE 8-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE).

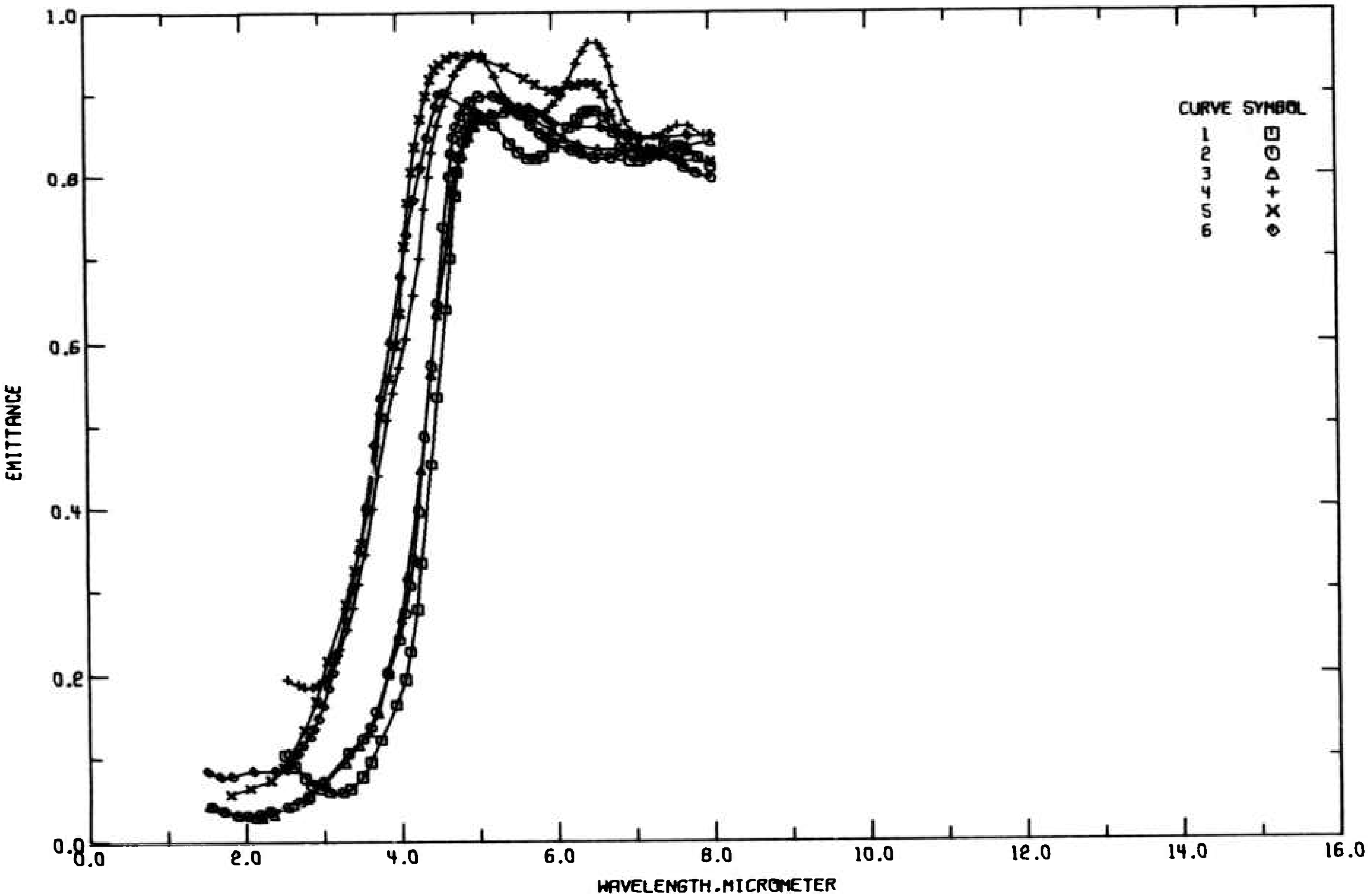


FIGURE 8-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE).

TABLE 8-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF CALCIUM ALUMINUM SILICATE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00009	Kandrach, G.S.	1975	2.5-8.0	473	Corning 9753	Specimen 0.3175 cm (1/8 in.) thick; spectral emittance; smooth values from figure.
2	A00009	Kandrach, G.S.	1975	1.6-8.0	673	Corning 9753	Similar to the above specimen.
3	A00009	Kandrach, G.S.	1975	1.5-8.0	873	Corning 9753	Similar to the above specimen.
4	A00009	Kandrach, G.S.	1975	2.5-7.9	473	Corning 9753	Specimen 1.27 cm (1/2 in.) thick; spectral emittance; smooth values from figure.
5	A00009	Kandrach, G.S.	1975	1.8-8.0	673	Corning 9753	Similar to the above specimen.
6	A00009	Kandrach, G.S.	1975	1.5-8.0	873	Corning 9753	Similar to the above specimen.

TABLE 8-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 1	
T = 473.	
2.47	0.103
2.59	0.090
2.73	0.077
2.81	0.069
2.91	0.065
3.04	0.060
3.21	0.060
3.31	0.065
3.46	0.079
3.57	0.095
3.70	0.122
3.90	0.167
4.02	0.195
4.09	0.227
4.18	0.278
4.24	0.332
4.36	0.453
4.46	0.534
4.58	0.643
4.64	0.700
4.71	0.775
4.74	0.805
4.77	0.823
4.82	0.841
4.87	0.854
4.91	0.860
4.96	0.869
5.08	0.869
5.22	0.860
5.42	0.835
5.53	0.828
5.65	0.820
5.76	0.820
5.85	0.824
5.98	0.835
6.18	0.858
6.29	0.869
6.38	0.876
6.43	0.879

λ	ε
CURVE	1 (CONT.)
6.53	0.679
6.64	0.871
6.76	0.852
6.86	0.833
6.97	0.818
7.09	0.818
7.18	0.820
7.42	0.835
7.59	0.835
7.68	0.831
7.84	0.822
8.00	0.811
CURVE 2	
T = 673.	
1.55	0.042
1.70	0.036
1.88	0.030
2.01	0.030
2.17	0.032
2.30	0.036
2.52	0.041
2.67	0.048
2.78	0.055
2.98	0.073
3.30	0.106
3.49	0.124
3.59	0.140
3.66	0.159
3.82	0.202
3.97	0.242
4.04	0.274
4.11	0.307
4.16	0.337
4.23	0.397
4.31	0.488
4.41	0.574
4.49	0.647
4.58	0.737

λ	ε
CURVE	2 (CONT.)
4.66	0.799
4.69	0.827
4.72	0.846
4.76	0.859
4.81	0.873
4.88	0.882
4.94	0.891
5.05	0.898
5.24	0.898
5.33	0.895
5.44	0.887
5.58	0.874
5.71	0.861
5.83	0.851
5.91	0.846
6.00	0.840
6.22	0.832
6.35	0.828
6.51	0.822
6.72	0.822
6.85	0.825
7.09	0.831
7.26	0.831
7.36	0.827
7.66	0.810
7.81	0.804
8.00	0.798
CURVE 3	
T = 873.	
1.52	0.043
1.88	0.032
2.10	0.028
2.19	0.028
2.34	0.032
2.59	0.045
2.76	0.053
2.99	0.073
3.26	0.096

λ	ε
CURVE	3 (CONT.)
3.44	0.116
3.56	0.133
3.69	0.159
3.82	0.204
3.99	0.267
4.08	0.317
4.26	0.446
4.40	0.565
4.48	0.635
4.63	0.721
4.70	0.783
4.75	0.807
4.82	0.827
4.91	0.848
4.99	0.860
5.09	0.869
5.20	0.876
5.36	0.878
5.55	0.878
5.67	0.875
5.99	0.855
6.12	0.846
6.32	0.838
6.57	0.832
7.20	0.833
7.50	0.830
7.70	0.835
8.00	0.842
CURVE 4	
T = 473.	
2.52	0.196
2.66	0.190
2.74	0.187
2.84	0.187
2.92	0.190
3.00	0.195
3.06	0.200
3.13	0.215

λ	ε
CURVE	4 (CONT.)
3.20	0.230
3.29	0.254
3.37	0.280
3.44	0.308
3.53	0.343
3.63	0.400
3.70	0.438
3.83	0.507
3.91	0.540
3.99	0.572
4.08	0.605
4.18	0.657
4.26	0.700
4.33	0.759
4.39	0.799
4.43	0.829
4.51	0.861
4.58	0.886
4.65	0.903
4.73	0.923
4.82	0.933
4.89	0.941
4.97	0.948
5.08	0.948
5.14	0.939
5.25	0.921
5.38	0.896
5.45	0.886
5.52	0.880
5.63	0.874
5.78	0.874
5.90	0.878
5.99	0.887
6.09	0.897
6.18	0.914
6.29	0.936
6.37	0.951
6.45	0.963
6.56	0.963
6.62	0.955

λ	ε
CURVE	4 (CONT.)
6.66	0.945
6.71	0.932
6.76	0.910
6.82	0.891
6.91	0.857
6.99	0.853
7.11	0.847
7.28	0.847
7.46	0.855
7.58	0.861
7.72	0.861
7.92	0.849
CURVE 5	
T = 673.	
1.79	0.058
2.04	0.066
2.30	0.075
2.47	0.089
2.58	0.105
2.74	0.136
2.89	0.171
3.04	0.216
3.28	0.284
3.40	0.323
3.48	0.358
3.57	0.398
3.66	0.446
3.75	0.510
3.86	0.560
3.95	0.599
4.01	0.636
4.07	0.714
4.12	0.767
4.17	0.805
4.22	0.835
4.29	0.869
4.36	0.893
4.42	0.918

TABLE 8-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE	5(CONT.)
4.48	0.929
4.55	0.935
4.64	0.942
4.74	0.947
4.94	0.947
5.13	0.943
5.39	0.932
5.63	0.919
5.77	0.912
5.96	0.904
6.09	0.904
6.28	0.910
6.38	0.913
6.49	0.913
6.56	0.909
6.63	0.900
6.73	0.877
6.81	0.858
6.88	0.850
6.96	0.841
7.03	0.834
7.17	0.829
7.31	0.824
7.61	0.821
8.00	0.818
CURVE 6	
T = 873.	
1.50	0.086
1.65	0.080
1.81	0.080
2.08	0.085
2.36	0.085
2.49	0.083
2.56	0.095
2.65	0.106
2.72	0.116
2.81	0.125
2.86	0.138

λ	ε
CURVE	6(CONT.)
2.92	0.151
2.98	0.167
3.05	0.187
3.11	0.204
3.16	0.224
3.27	0.267
3.36	0.303
3.45	0.346
3.55	0.400
3.66	0.478
3.75	0.533
3.88	0.601
4.02	0.679
4.10	0.729
4.20	0.771
4.29	0.811
4.38	0.845
4.49	0.885
4.53	0.900
4.60	0.902
4.98	0.861
5.08	0.874
5.25	0.874
5.42	0.880
5.50	0.882
5.57	0.884
5.69	0.884
5.80	0.877
5.91	0.870
6.00	0.864
6.30	0.861
6.60	0.859
6.91	0.849
7.09	0.845
7.41	0.845
7.70	0.849
8.00	0.849

b. Normal Spectral Emittance (Temperature Dependence)

No original experimental data were located for the temperature dependence of the normal spectral emittance of Corning 9753. However, using the interpolated values of curves 1, 2, and 3 of Figure 8-1 and Table 8-3, provisional values for a specimen thickness of 3.175 mm have been derived for 2.8, 3.8, and 5.0 μm. These provisional values are listed in Table 8-4 and shown in Figure 8-3. The uncertainty of the provisional values is within 30%. It is noted these values only go to 873 K and there are no values for higher temperatures for the thickness of 3.175 mm.

It is observed that the value of normal spectral emittance of Corning 9753 over the temperature range of 473 to 873 K is a constant, to a first approximation. Assuming that this constancy extends to the melting range of 1723 to 1773 K, it would be concluded that, in that temperature range, the numerical value of the normal spectral emittance of Corning 9753 would be 0.06 at 2.8 μm, 0.2 at 3.8 μm, and 0.9 at 5.0 μm.

TABLE 8-4. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF CALCIUM ALUMINUM SILICATE (CORNING 9753) (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ	T	ϵ	T	ϵ
3.175MM THICK		3.175MM THICK		3.175MM THICK	
λ = 2.8		λ = 3.8		λ = 5.0	
473.	0.068	473.	0.144	473.	0.869
673.	0.057	673.	0.198	673.	0.895
873.	0.057	873.	0.199	873.	0.861

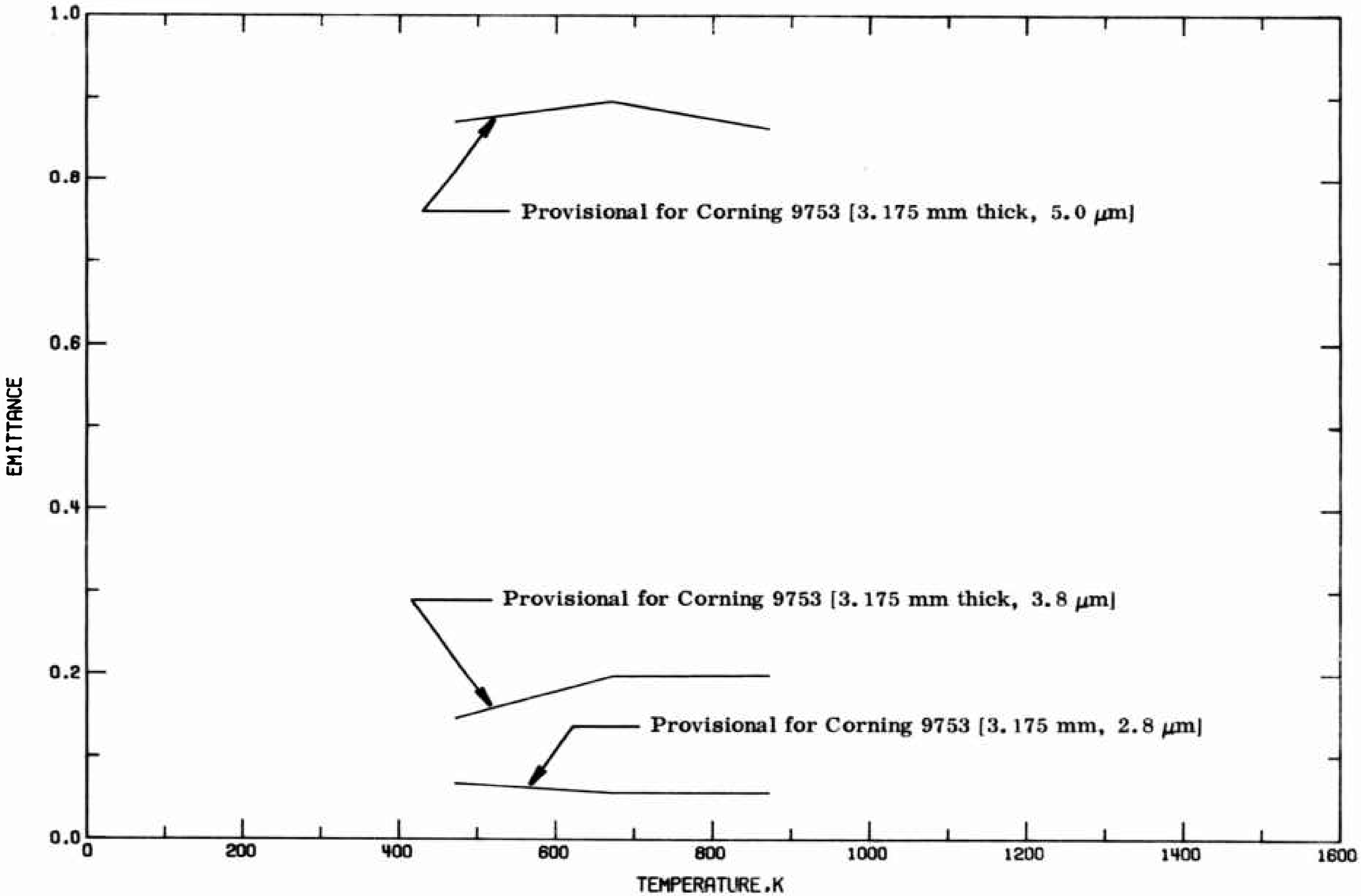


FIGURE 8-3. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF CALCIUM ALUMINUM SILICATE (TEMPERATURE DEPENDENCE).

c. Normal Spectral Reflectance (Wavelength Dependence)

Only one data set was found for the wavelength dependence of the normal spectral reflectance. This is curve number 5 (T = 293 K, specimen thickness 1.99 mm) with the data listed in Table 8-7 and shown in Figures 8-4 and 8-5. Specimen characterization and measurement information for the data set are given in Table 8-6.

Values for other conditions have been generated for the normal spectral reflectance. Values for curve number 1 in Tables 8-6 and 8-7 were calculated using equation (2.6-15) which holds for a polished, uncoated, plane-parallel plate, taking into account multiple internal reflectance, and assuming zero absorption. The refractive index data was taken from curve number 1 in Table 8-9 and shown in Figure 8-6. Specimen characterization and measurement information for the refractive index data are given in Table 8-8.

Values of reflectance for a specimen thickness of 3.175 mm at 473, 673, and 873 K were calculated from normal transmittance and normal emittance data with details of the calculation mentioned in Table 8-6 for curves 2, 3, and 4.

Two provisional curves are given with one applicable to T = 293 K and a specimen thickness of 1.99 mm and the other for T = 873 K and a specimen thickness of 3.175 mm. The latter is shown to give an indication of the effect of temperature and thickness change. The uncertainty of these values can be large because of the small values of reflectance involved. However, over most of the wavelength region, the uncertainty should not exceed 30%. The provisional values are listed in Table 8-5 and shown in Figure 8-4.

It is noted that no reflectance data are available above 873 K and even the values for 473, 673, and 873 K do not go beyond 8 μm.

TABLE 8-5. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF CALCIUM ALUMINUM SILICATE (CORNING 9753) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
1.99MM THICK	
T = 293	
0.40	0.104
0.50	0.103
0.60	0.102
0.70	0.101
0.80	0.100
0.90	0.100
1.00	0.099
1.10	0.099
1.20	0.099
1.30	0.098
1.40	0.098
1.50	0.098
1.60	0.098
1.70	0.097
1.80	0.097
1.90	0.096
2.00	0.096
2.10	0.096
2.20	0.095
2.30	0.095
2.40	0.094
2.50	0.094
2.60	0.093
2.70	0.093
2.80	0.092
2.90	0.091
3.00	0.091
3.10	0.090
3.20	0.090
3.30	0.089
3.40	0.088
3.50	0.088
3.60	0.086
3.70	0.085
3.80	0.084
3.90	0.084
4.00	0.084
4.10	0.079
4.20	0.075

λ	ρ
1.99MM THICK	
T = 293 (CONT.)	
4.30	0.075
4.40	0.065
4.50	0.047
4.60	0.040
4.70	0.038
4.80	0.037
4.90	0.036
5.00	0.035
5.10	0.034
5.20	0.034
5.30	0.033
5.40	0.033
5.50	0.032
6.60	0.032
5.70	0.031
5.80	0.031
5.90	0.030
6.00	0.030
6.10	0.029
6.20	0.029
6.30	0.028
6.40	0.027
6.50	0.026
6.60	0.025
6.70	0.024
6.80	0.023
6.90	0.022
7.00	0.021
7.10	0.020
7.20	0.019
7.30	0.018
7.40	0.017
7.50	0.016
7.60	0.014
7.70	0.013
7.80	0.011
7.90	0.010
8.00	0.004
8.10	0.000

λ	ρ
1.99MM THICK	
T = 293 (CONT.)	
8.20	0.000
8.30	0.000
8.40	0.000
8.50	0.000
8.60	0.000
8.70	0.002
8.80	0.010
8.90	0.018
9.00	0.027
9.10	0.035
9.20	0.046
9.30	0.066
9.40	0.098
9.50	0.114
9.60	0.127
9.70	0.136
9.80	0.144
9.90	0.152
10.0	0.159
10.1	0.168
10.2	0.175
10.3	0.175
10.4	0.180
10.5	0.180
10.6	0.180
10.7	0.179
10.8	0.178
10.9	0.177
11.0	0.174
11.1	0.163
11.2	0.161
11.3	0.156
11.4	0.151
11.5	0.145
11.6	0.140
11.7	0.134
11.8	0.129
11.9	0.124
12.0	0.120

λ	ρ
1.99MM THICK	
T = 293 (CONT.)	
12.1	0.115
12.2	0.110
12.3	0.103
12.4	0.095
12.5	0.090
12.6	0.086
12.7	0.084
12.8	0.084
12.9	0.084
13.0	0.084
13.1	0.084
13.2	0.084
13.3	0.084
13.4	0.084
13.5	0.085
13.6	0.086
13.7	0.088
13.8	0.090
13.9	0.092
14.0	0.095
14.1	0.099
14.2	0.104
14.3	0.110
14.4	0.115
14.5	0.118
14.6	0.121
14.7	0.123
14.8	0.127
14.9	0.134

λ	ρ
3.175MM THICK	
T = 873	
2.00	0.125
2.10	0.120
2.20	0.115
2.30	0.107
2.40	0.099
2.50	0.083
2.60	0.077
2.80	0.102
2.90	0.105
3.00	0.092
3.10	0.082
3.20	0.076
3.30	0.071
3.40	0.068
3.50	0.078
3.60	0.102
3.70	0.092
3.80	0.073
3.90	0.058
4.00	0.049
4.10	0.040
4.20	0.016
4.30	0.022
4.40	0.040
4.50	0.064
4.60	0.102
4.70	0.105
4.80	0.123
4.90	0.139
5.00	0.139
5.10	0.130
5.20	0.124
5.30	0.122
5.40	0.121
5.50	0.120
5.60	0.122
5.70	0.127
5.80	0.134
5.90	0.140

λ	ρ
3.175MM THICK	
T = 873 (CONT.)	
6.00	0.146
6.10	0.153
6.20	0.158
6.30	0.161
6.40	0.164
6.50	0.166
6.60	0.168
6.70	0.168
6.80	0.168
6.90	0.167
7.00	0.167
7.10	0.167
7.20	0.167
7.30	0.168
7.40	0.169
7.50	0.170
7.60	0.168
7.70	0.165
7.80	0.163
7.90	0.161
8.00	0.158

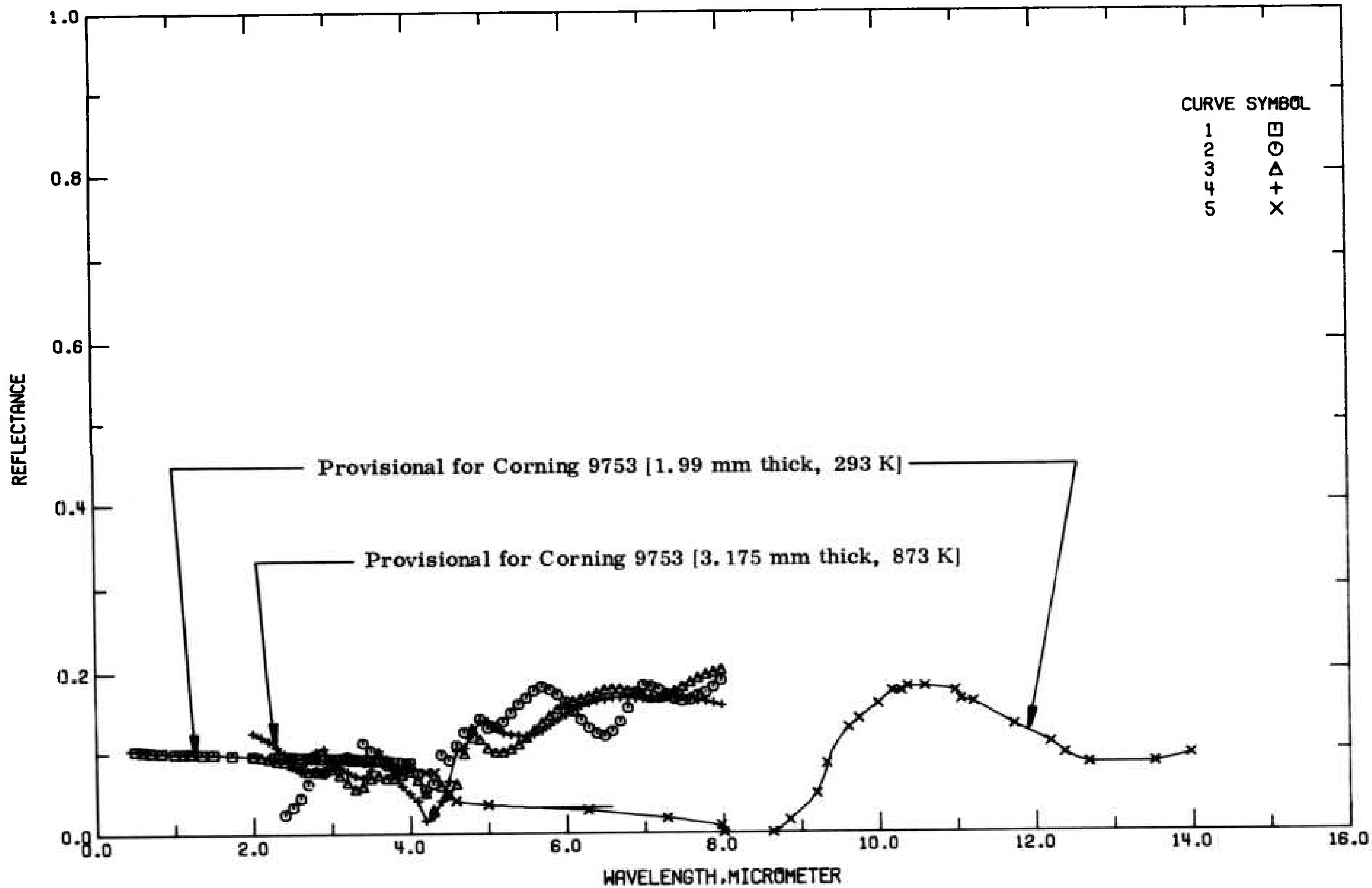


FIGURE 8-4. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE).

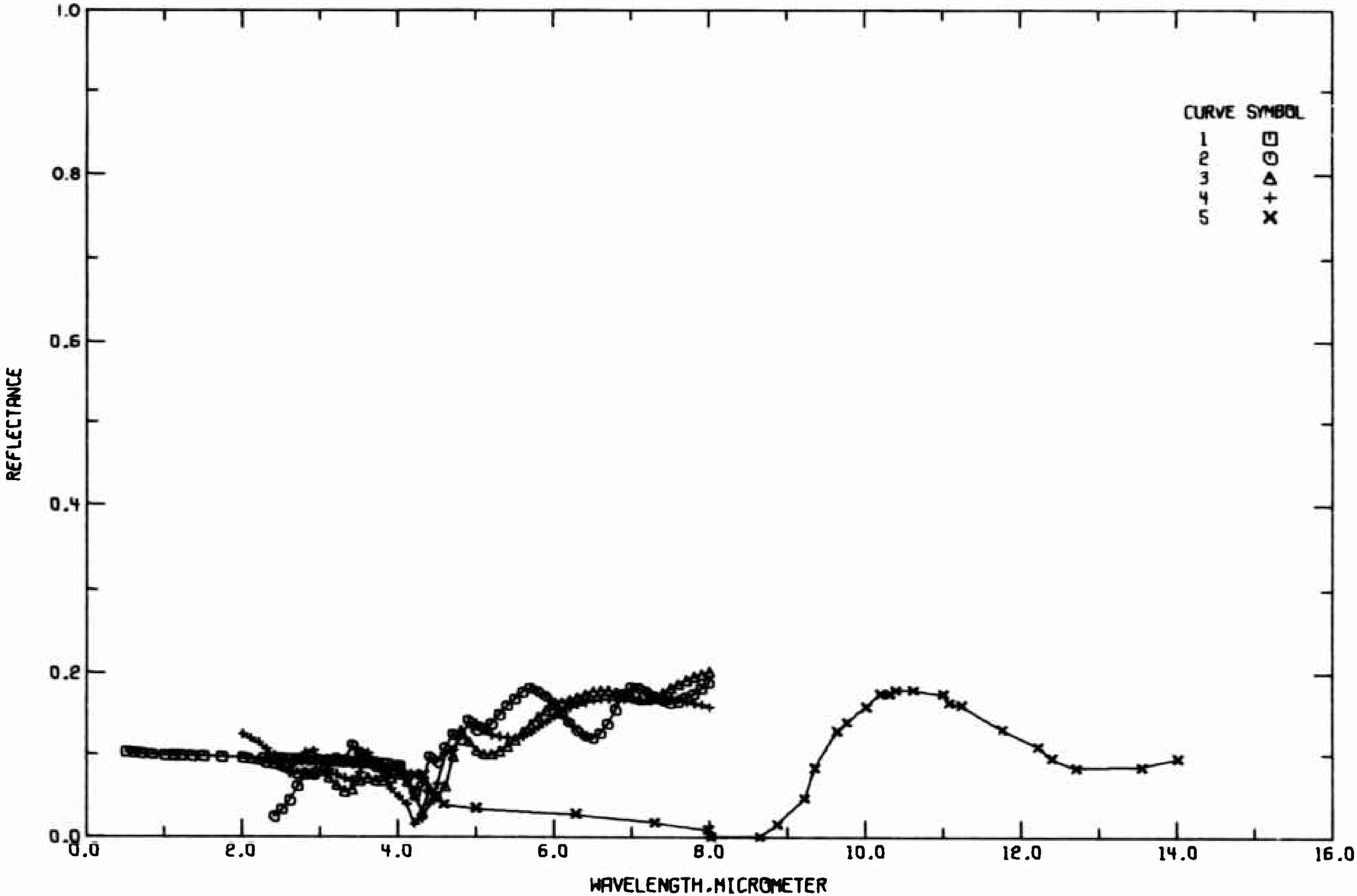


FIGURE 8-5. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE).

TABLE 8-6. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF CALCIUM ALUMINUM SILICATE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	E62600, A00009			0.50-4.0	293	Glass 9753	Calculated from refractive index data [see Ref. A00009] and using $(n-1)^2/(n^2+1)$ which applies to a polished, uncoated, plane-parallel plate, takes into account multiple internal reflections, and assumes zero absorption; measurement temperature for refractive index data not given explicitly, assumed to be 293 K.
2	A00009			2.4-8.0	473	Corning 9753	Specimen thickness 0.3175 cm (1/8 in.); calculated using $\rho = 1.0 - \alpha - \tau$, and $\alpha = \epsilon$, where data for ϵ from curve no. 1 of Tables 8-2 and 8-3, data for τ from curve no. 7 of Tables 8-13 and 8-14, from 4.9 to 8.0 μm, τ taken to be 0.000.
3	A00009			2.0-8.0	673	Corning 9753	Specimen thickness 0.3175 cm (1/8 in.); calculated using $\rho = 1.0 - \alpha - \tau$ and $\alpha = \epsilon$ where data for ϵ from curve no. 2 of Tables 8-2 and 8-3, data for τ from curve no. 8 of Tables 8-13 and 8-14, from 4.80 to 8.0 μm, τ taken to be 0.000.
4	A00009			2.0-8.0	873	Corning 9753	Specimen thickness 0.3175 cm (1/8 in.); calculated using $\rho = 1.0 - \alpha - \tau$ and $\alpha = \epsilon$ where data for ϵ from curve no. 3 of Tables 8-2 and 8-3, data for τ from curve no. 9 of Tables 8-13 and 8-14, from 4.94 to 8.0 τ taken to be 0.000.
5	A00013	Plummer, W.A.		2.5-15	293	Code 9753	Specimen 1.99 mm thick; reflectance vs. aluminum reported; Perkin-Elmer Model 221 infrared spectrophotometer used; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K.

TABLE 8-7. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

CURVE 1
T = 293.

λ	ρ
0.500	0.103
0.594	0.102
0.694	0.101
0.834	0.100
1.001	0.099
1.112	0.099
1.202	0.099
1.346	0.098
1.495	0.098
1.730	0.097
2.003	0.096
2.274	0.095
2.489	0.095
2.613	0.094
2.707	0.094
2.852	0.093
2.987	0.093
3.112	0.092
3.260	0.091
3.392	0.091
3.495	0.090
3.610	0.090
3.723	0.089
3.847	0.088
4.000	0.087

CURVE 2
T = 473.

λ	ρ
2.40	0.024
2.50	0.033
2.60	0.044
2.70	0.061
2.80	0.070
2.90	0.075
3.00	0.084
3.10	0.093
3.20	0.095
3.30	0.092
3.40	0.112
3.50	0.102
3.60	0.092
3.70	0.085
3.80	0.081
3.90	0.078
4.00	0.081
4.10	0.073
4.20	0.054
4.30	0.061
4.40	0.097
4.50	0.096
4.60	0.105
4.70	0.125
4.80	0.118
4.90	0.142
5.00	0.135
5.10	0.132
5.20	0.136
5.30	0.149
5.40	0.160
5.50	0.168
5.60	0.177
5.70	0.182
5.80	0.175
5.90	0.172
6.00	0.163
6.10	0.151
6.20	0.140
6.30	0.130
6.40	0.123
6.50	0.120
6.60	0.126
6.70	0.138
6.80	0.155
6.90	0.174
7.00	0.183
7.10	0.182
7.20	0.178
7.30	0.172
7.40	0.166
7.50	0.163
7.60	0.165
7.70	0.170
7.80	0.174
7.90	0.181
8.00	0.189

CURVE 3
T = 673.

λ	ρ
2.00	0.096
2.10	0.095
2.20	0.093
2.30	0.090
2.40	0.089
2.50	0.086
2.60	0.082
2.70	0.077
2.80	0.078
2.90	0.078
3.00	0.080
3.10	0.072
3.20	0.063
3.30	0.055
3.40	0.058
3.50	0.068
3.60	0.072
3.70	0.068
3.80	0.068
3.90	0.072
4.00	0.076
4.10	0.066
4.20	0.050
4.30	0.030
4.40	0.058
4.50	0.043
4.60	0.061
4.70	0.098
4.80	0.130
4.90	0.116
5.00	0.105
5.10	0.100
5.20	0.100
5.30	0.104
5.40	0.110
5.50	0.118
5.60	0.128
5.70	0.137
5.80	0.146
5.90	0.154
6.00	0.160
6.10	0.164
6.20	0.167
6.30	0.170
6.40	0.174
6.50	0.178
6.60	0.179
6.70	0.179
6.80	0.177
6.90	0.174
7.00	0.171
7.10	0.168
7.20	0.168
7.30	0.170
7.40	0.176
7.50	0.182
7.60	0.187
7.70	0.192
7.80	0.196
7.90	0.199
8.00	0.202

CURVE 4
T = 873.

λ	ρ
2.00	0.125
2.10	0.120
2.20	0.115
2.30	0.107
2.40	0.099
2.50	0.083
2.60	0.077
2.80	0.102
2.90	0.105
3.00	0.092
3.10	0.082
3.20	0.076
3.30	0.071
3.40	0.068
3.50	0.078
3.60	0.102
3.70	0.092
3.80	0.073
3.90	0.056
4.00	0.049
4.10	0.040
4.20	0.016
4.30	0.022
4.40	0.040
4.50	0.064
4.60	0.102
4.70	0.105
4.80	0.123
4.90	0.139
5.00	0.139
5.10	0.130
5.20	0.124
5.30	0.122
5.40	0.121
5.50	0.120
5.60	0.122
5.70	0.127
5.80	0.134
5.90	0.140
6.00	0.146
6.10	0.153
6.20	0.158
6.30	0.161
6.40	0.164
6.50	0.166
6.60	0.168
6.70	0.168
6.80	0.168
6.90	0.167
7.00	0.167
7.10	0.167
7.20	0.167
7.30	0.168
7.40	0.169
7.50	0.170
7.60	0.165
7.70	0.165
7.80	0.163
7.90	0.161
8.00	0.158

CURVE 5
T = 293.

λ	ρ
2.50	0.094
2.80	0.092
3.46	0.088
3.80	0.084
4.01	0.084
4.20	0.073
4.32	0.075
4.49	0.048
4.59	0.040
5.00	0.035
6.26	0.028
7.29	0.018
7.93	0.009
8.01	0.000
8.64	0.000
8.85	0.015
9.21	0.047
9.34	0.084
9.62	0.129
9.75	0.140

TABLE 8-7. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE	5 (CONT.)
10.00	0.159
10.19	0.175
10.30	0.175
10.38	0.180
10.60	0.180
10.99	0.175
11.06	0.164
11.22	0.161
11.74	0.132
12.20	0.113
12.38	0.096
12.69	0.084
13.53	0.085
13.99	0.095
14.21	0.105
14.49	0.118
14.79	0.125
14.87	0.136
14.92	0.133

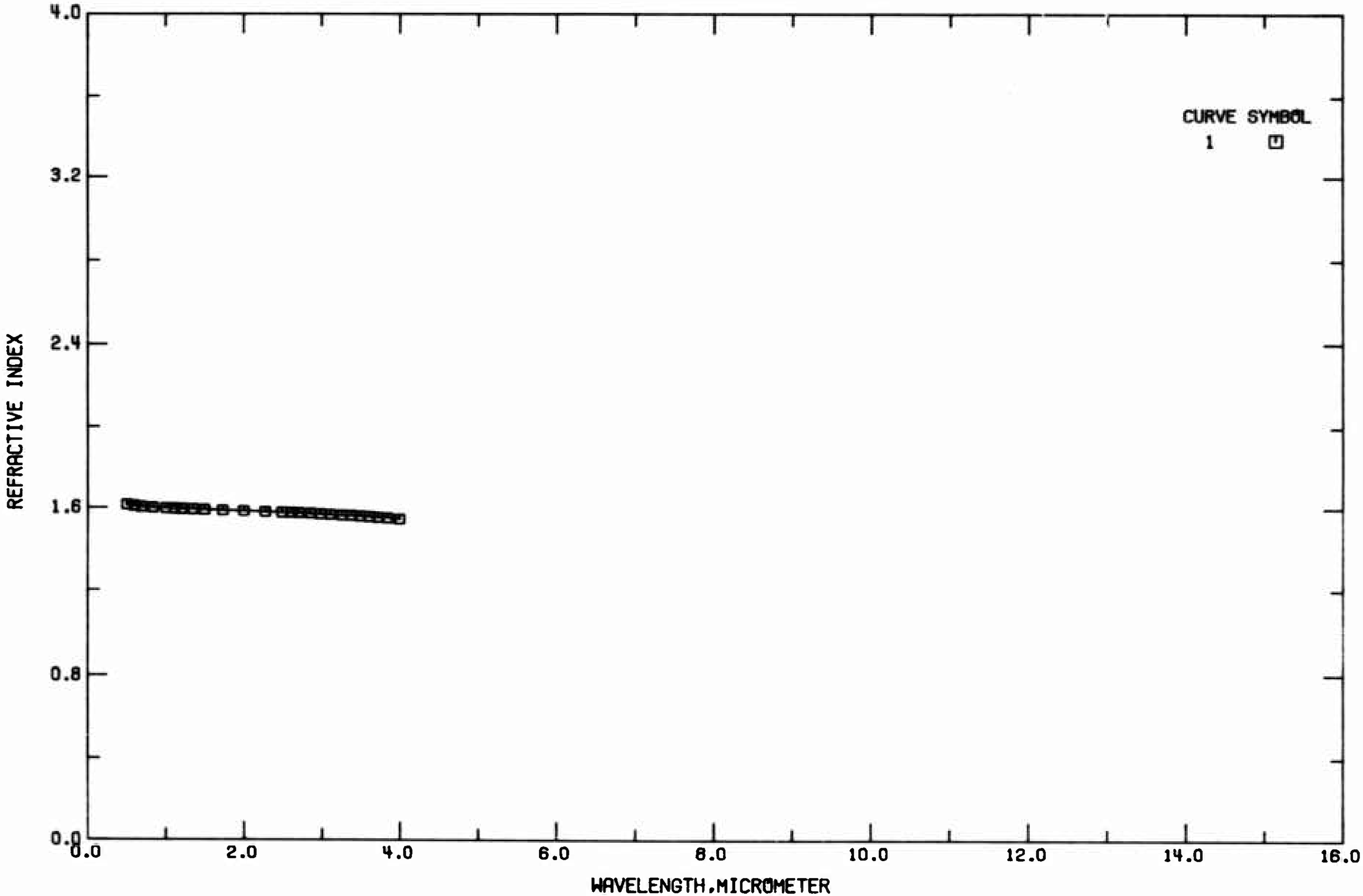


FIGURE 8-6. EXPERIMENTAL REFRACTIVE INDEX OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE).

TABLE 8-8. MEASUREMENT INFORMATION ON THE REFRACTIVE INDEX OF CALCIUM ALUMINUM SILICATE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00009	Kandrach, G.S.	1975	0.50–4.0	293	Glass 9753	Smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K.

TABLE 8-9. EXPERIMENTAL REFRACTIVE INDEX OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFRACTIVE INDEX, n]

λ	n
CURVE 1	
T = 293.	
0.500	1.6096
0.594	1.6040
0.694	1.6002
0.834	1.5965
1.001	1.5931
1.112	1.5914
1.202	1.5902
1.346	1.5883
1.495	1.5865
1.730	1.5837
2.000	1.5803
2.274	1.5767
2.469	1.5736
2.613	1.5717
2.707	1.5702
2.852	1.5679
2.987	1.5654
3.112	1.5630
3.260	1.5600
3.382	1.5576
3.495	1.5551
3.610	1.5525
3.723	1.5499
3.847	1.5467
4.000	1.5422

d. Normal Spectral Reflectance (Temperature Dependence)

Using values from curves 2, 3, and 4 of the previous section, provisional values have been generated for 2.8, 3.8, and 5.0 μm. These values listed in Table 8-10 and shown in Figure 8-7 are valid for a thickness of 3.175 mm. The uncertainty should not exceed 30%. Note that for the three lowest wavelengths, values are not given above 873 K and no values are given for 10.6 μm above room temperature.

TABLE 8-13. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF CALCIUM ALUMINUM SILICATE(CORNING 9753) (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

T	ρ	T	ρ	T	ρ
3.175MM THICK		3.175MM THICK		3.175MM THICK	
λ = 2.80		λ = 3.80		λ = 5.0	
473.	0.076	473.	0.081	473.	0.130
673.	0.078	673.	0.068	673.	0.105
873.	0.102	873.	0.073	873.	0.139

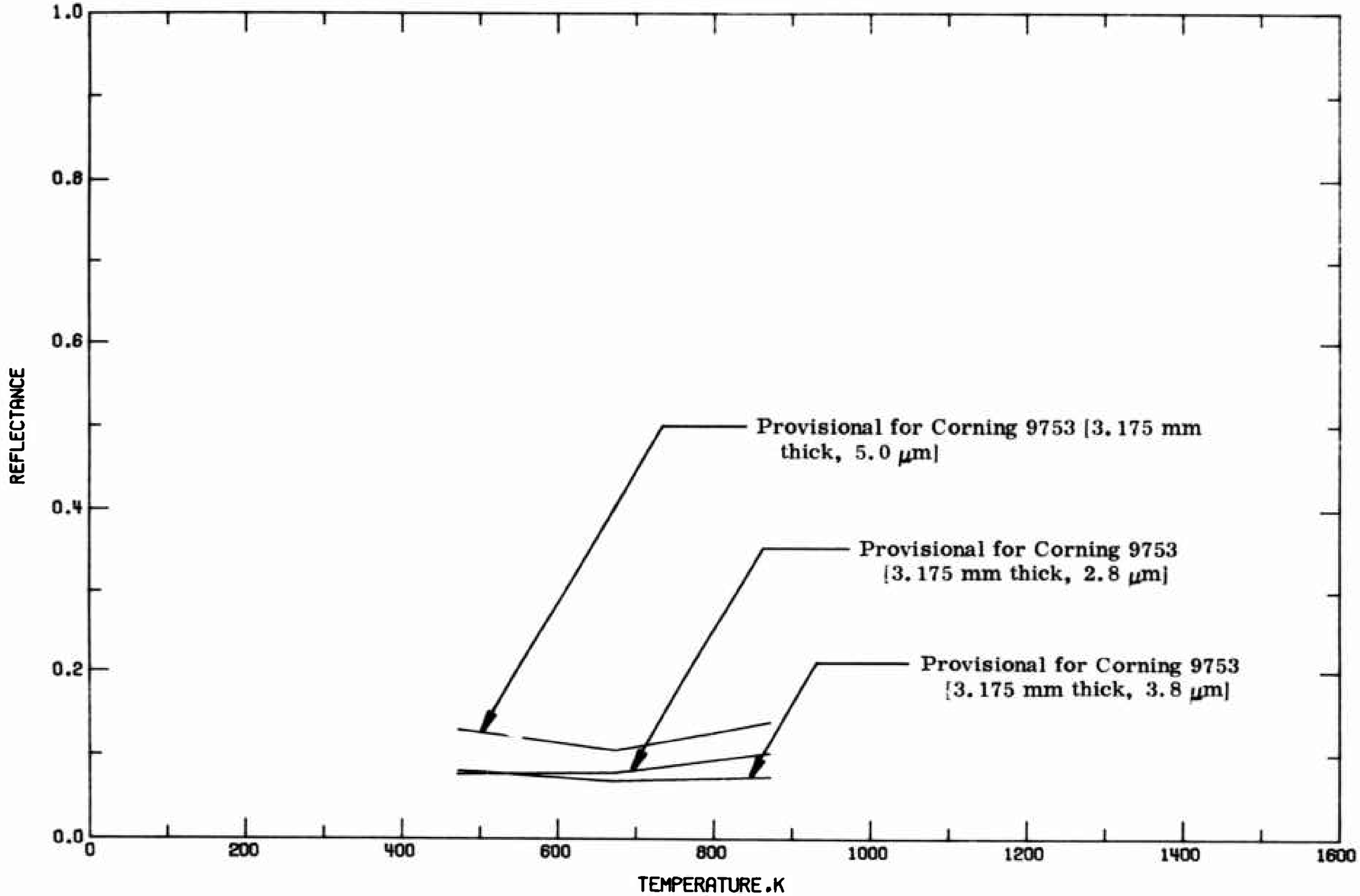


FIGURE 8-7. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF CALCIUM ALUMINUM SILICATE (TEMPERATURE DEPENDENCE).

e. Normal Spectral Absorptance (Wavelength Dependence)

No original experimental data were located for the normal spectral absorptance of Corning 9753. However, by applying Kirchhoff's law, the provisional values of the normal spectral absorptance are generated which are equal to the provisional values of the normal spectral emittance. For a discussion of the uncertainties see the section on the normal spectral emittance (wavelength dependence) of calcium aluminum silicate. The provisional values of the normal spectral absorptance are listed in Table 8-11 and shown in Figure 8-8.

For the temperature dependence of the normal spectral absorptance, see the section on the normal spectral emittance (temperature dependence) of calcium aluminum silicate.

TABLE 8-11. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF CALCIUM ALUMINUM SILICATE(CORNING 9753) (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α)

λ	α	λ	α	λ	α	λ	α	λ	α	λ	α
2.00MM THICK		2.00MM THICK		2.00MM THICK		2.00MM THICK		3.175MM THICK		3.175MM THICK	
T = 293		T = 293 (CONT.)		T = 293 (CONT.)		T = 293 (CONT.)		T = 473		T = 473 (CONT.)	
0.40	0.101	5.10	0.966	9.00	0.973	12.9	0.916	2.40	0.110	4.60	0.676
0.50	0.029	5.20	0.966	9.10	0.965	13.0	0.916	2.47	0.103	4.64	0.700
0.60	0.017	5.30	0.967	9.20	0.954	13.1	0.916	2.50	0.099	4.70	0.758
0.80	0.016	5.40	0.967	9.30	0.934	13.2	0.916	2.59	0.090	4.71	0.775
0.90	0.020	5.50	0.968	9.40	0.902	13.3	0.916	2.60	0.089	4.74	0.805
1.00	0.024	5.60	0.968	9.50	0.886	13.4	0.916	2.70	0.080	4.77	0.823
1.10	0.026	5.70	0.969	9.60	0.873	13.5	0.915	2.73	0.077	4.80	0.832
1.20	0.027	5.80	0.969	9.70	0.864	13.6	0.914	2.80	0.070	4.82	0.841
1.30	0.028	5.90	0.970	9.80	0.856	13.7	0.912	2.81	0.069	4.87	0.854
1.40	0.028	6.00	0.970	9.90	0.848	13.8	0.910	2.90	0.065	4.90	0.858
1.50	0.028	6.10	0.971	10.0	0.841	13.9	0.908	2.91	0.065	4.91	0.860
1.60	0.027	6.20	0.971	10.1	0.832	14.0	0.905	3.00	0.061	4.96	0.869
1.70	0.027	6.30	0.972	10.2	0.825	14.1	0.901	3.04	0.060	5.00	0.870
1.80	0.026	6.40	0.973	10.3	0.825	14.2	0.896	3.10	0.059	5.08	0.869
2.00	0.026	6.50	0.974	10.4	0.820	14.3	0.890	3.20	0.060	5.10	0.868
2.30	0.025	6.60	0.975	10.5	0.820	14.4	0.885	3.21	0.060	5.20	0.862
2.40	0.026	6.70	0.976	10.6	0.820	14.5	0.882	3.30	0.064	5.22	0.860
2.50	0.027	6.80	0.977	10.7	0.821	14.6	0.879	3.31	0.065	5.30	0.851
2.60	0.031	6.90	0.978	10.8	0.822	14.7	0.877	3.40	0.073	5.40	0.840
2.70	0.036	7.00	0.979	10.9	0.823	14.8	0.873	3.46	0.079	5.42	0.838
2.80	0.048	7.10	0.980	11.0	0.826	14.9	0.866	3.50	0.084	5.50	0.832
2.90	0.062	7.20	0.981	11.1	0.837			3.57	0.095	5.53	0.828
3.20	0.066	7.30	0.982	11.2	0.839			3.60	0.101	5.60	0.823
3.30	0.064	7.40	0.983	11.3	0.844			3.70	0.122	5.65	0.820
3.40	0.064	7.50	0.984	11.4	0.849			3.80	0.144	5.70	0.818
3.50	0.064	7.60	0.986	11.5	0.855			3.90	0.167	5.76	0.820
3.80	0.086	7.70	0.987	11.6	0.860			4.00	0.190	5.80	0.822
3.90	0.100	7.80	0.989	11.7	0.866			4.02	0.195	5.85	0.824
4.00	0.118	7.90	0.990	11.8	0.871			4.09	0.227	5.93	0.828
4.10	0.151	8.00	0.996	11.9	0.876			4.10	0.229	5.98	0.835
4.20	0.202	8.10	1.00	12.0	0.880			4.18	0.278	6.03	0.837
4.30	0.272	8.20	1.00	12.1	0.885			4.20	0.294	6.10	0.849
4.40	0.391	8.30	1.00	12.2	0.890			4.24	0.332	6.18	0.858
4.50	0.543	8.40	1.00	12.3	0.897			4.30	0.383	6.20	0.860
4.60	0.715	8.50	1.00	12.4	0.905			4.38	0.453	6.29	0.869
4.70	0.824	8.60	1.00	12.5	0.910			4.40	0.469	6.30	0.870
4.80	0.900	8.70	0.998	12.6	0.914			4.46	0.534	6.39	0.876
4.90	0.944	8.80	0.990	12.7	0.916			4.50	0.580	6.40	0.877
5.00	0.965	8.90	0.982	12.8	0.916			4.58	0.648	6.43	0.879

E 8-11. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF CALCIUM ALUMINUM SILICATE(CORNING 9733) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α	λ	α
3.175MM THICK		3.175MM THICK		3.175MM THICK		3.175MM THICK	
T = 473 (CONT.)		T = 873		T = 873 (CONT.)		T = 873 (CONT.)	
6.50	0.880	1.52	0.043	4.10	0.328	6.57	0.832
6.53	0.873	1.60	0.041	4.20	0.402	6.60	0.832
6.60	0.874	1.70	0.037	4.26	0.446	6.70	0.832
6.64	0.871	1.80	0.034	4.30	0.480	6.80	0.832
6.70	0.862	1.88	0.032	4.40	0.565	6.90	0.833
6.76	0.852	1.90	0.031	4.48	0.635	7.00	0.833
6.80	0.845	2.00	0.030	4.50	0.640	7.10	0.833
6.86	0.833	2.10	0.028	4.60	0.702	7.20	0.833
6.90	0.826	2.19	0.028	4.63	0.721	7.30	0.832
6.97	0.818	2.20	0.028	4.70	0.783	7.40	0.831
7.00	0.817	2.30	0.031	4.75	0.807	7.50	0.830
7.09	0.818	2.34	0.032	4.80	0.819	7.60	0.832
7.10	0.818	2.40	0.035	4.82	0.827	7.70	0.835
7.18	0.820	2.50	0.040	4.90	0.846	7.80	0.837
7.20	0.822	2.59	0.045	4.91	0.848	7.90	0.839
7.30	0.828	2.60	0.046	4.99	0.860	8.00	0.842
7.40	0.834	2.70	0.051	5.00	0.861		
7.42	0.835	2.76	0.053	5.09	0.869		
7.50	0.837	2.80	0.056	5.10	0.870		
7.59	0.835	2.90	0.066	5.20	0.876		
7.60	0.835	2.99	0.073	5.33	0.878		
7.68	0.831	3.00	0.074	5.36	0.878		
7.70	0.830	3.10	0.082	5.40	0.879		
7.80	0.825	3.20	0.090	5.50	0.880		
7.84	0.822	3.26	0.096	5.55	0.878		
7.90	0.819	3.30	0.099	5.60	0.878		
8.00	0.811	3.40	0.111	5.67	0.875		
		3.44	0.116	5.70	0.873		
		3.50	0.124	5.80	0.866		
		3.56	0.133	5.90	0.860		
		3.60	0.140	5.99	0.855		
		3.69	0.159	6.00	0.854		
		3.70	0.163	6.10	0.847		
		3.80	0.196	6.12	0.846		
		3.82	0.204	6.20	0.842		
		3.90	0.232	6.30	0.839		
		3.99	0.267	6.32	0.838		
		4.00	0.273	6.40	0.836		
		4.08	0.317	6.50	0.834		

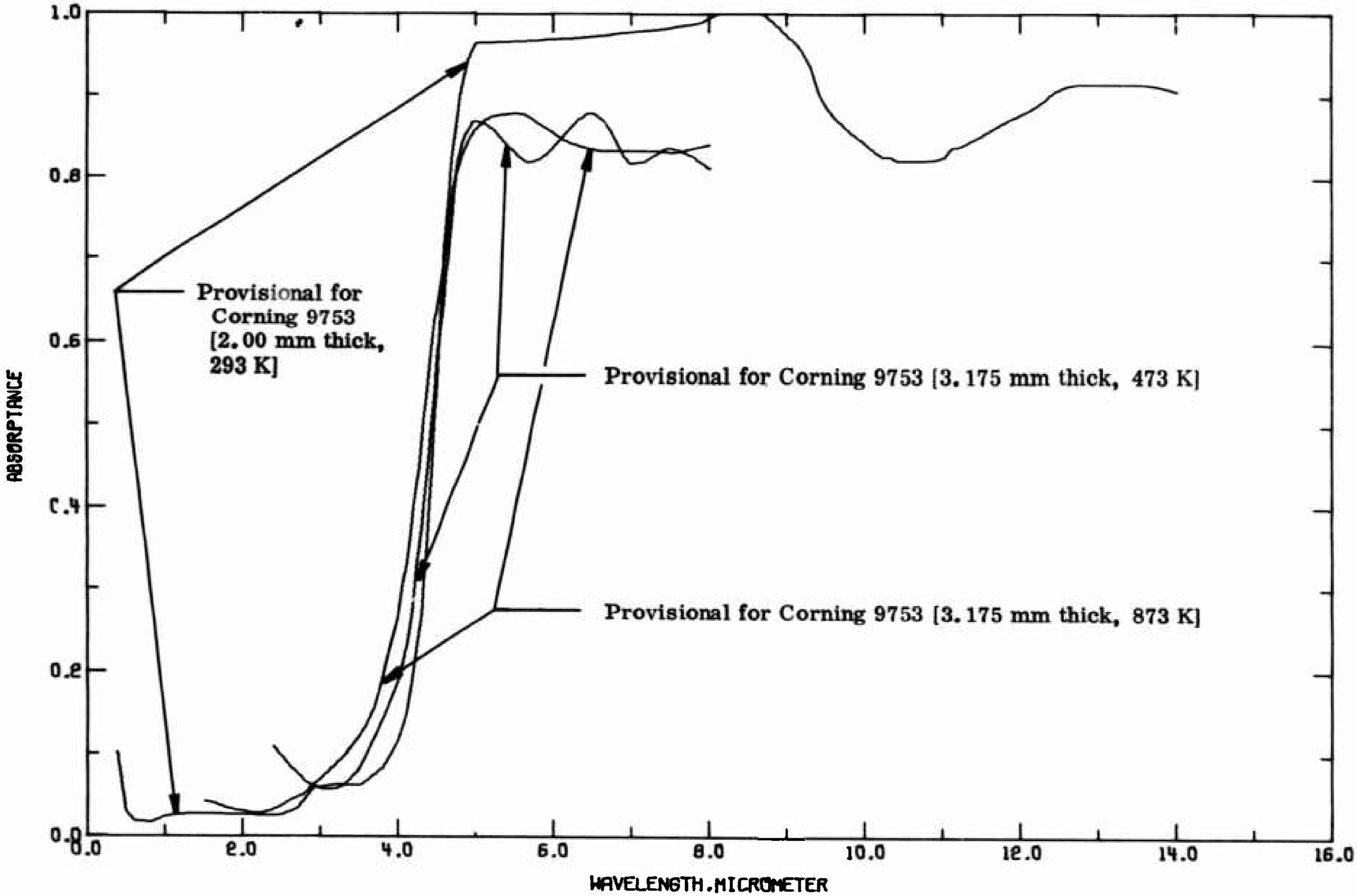


FIGURE 8-8. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE).

f. Normal Spectral Transmittance (Wavelength Dependence)

There are 17 sets of experimental data available for the wavelength dependence of the normal spectral transmittance of calcium aluminum silicate, 13 of which apply to Corning 9753. The data is listed in Table 8-14 and shown in Figures 8-9 and 8-10. Specimen characterization and measurement information for the data are given in Table 8-13.

There are three data sets which are for a specimen thickness of 2.00 mm at room temperature (curves 1, 4, and 5). These three curves were used to determine a provisional curve. The provisional values are listed in Table 8-12 and shown in Figure 8-9. For values of transmittance over 0.5, the uncertainty is within 5% but around a transmittance value of 0.1, the uncertainty can reach 20%. These uncertainties are determined taking into account the slightly different thicknesses and the slightly different temperatures of the specimens for the data sets that formed the basis of these provisional value sets.

In order to show the effect of temperature on the normal spectral transmittance of Corning 9753, another provisional curve is given and is applicable to a specimen 2.00 mm thick at a temperature of 1173K. The provisional values are listed in Table 8-12 and shown in Figure 8-9. The uncertainty is within 20% for this set of values.

It is noted that the provisional curve for 1173 K is above the provisional curve for 293 K in the region 1 to about 2.7 μm. However, the provisional curve for 1173 K is below the provisional curve for 293 K in the wavelength region of 3.3 to 4.9 μm.

For a specimen of 2.00 mm thick there is no normal spectral transmittance data above 1173 K and only one set available between 1173 K and room temperature. For specimen thicknesses of 3.175 and 12.7 mm, the highest temperature for which normal spectral transmittance data is available is 873 K.

TABLE 8-12. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF CALCIUM ALUMINUM SILICATE(CORNING 9753) (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
.00MM THICK		2.00MM THICK		2.00MM THICK		2.00MM THICK		2.00MM THICK	
= 293		T = 293 (CONT.)		T = 293 (CONT.)		T = 1173		T = 1173 (CONT.)	
0.319	0.000	2.30	0.880	4.75	0.101	1.00	0.887	3.69	0.739
0.324	0.023	2.40	0.880	4.79	0.069	1.10	0.891	3.70	0.736
0.331	0.069	2.50	0.879	4.80	0.063	1.11	0.891	3.79	0.707
0.337	0.108	2.60	0.876	4.83	0.047	1.20	0.892	3.80	0.704
0.341	0.141	2.70	0.871	4.87	0.028	1.30	0.892	3.85	0.681
0.345	0.204	2.80	0.860	4.90	0.020	1.40	0.892	3.90	0.660
0.353	0.352	2.86	0.850	4.92	0.014	1.50	0.892	3.94	0.640
0.359	0.460	2.90	0.847	4.95	0.004	1.60	0.891	4.00	0.610
0.364	0.538	2.98	0.843	5.00	0.000	1.62	0.891	4.02	0.602
0.371	0.626	3.08	0.842			1.70	0.890	4.10	0.555
0.377	0.674	3.16	0.843			1.80	0.890	4.17	0.506
0.387	0.734	3.20	0.844			1.90	0.889	4.20	0.486
0.394	0.771	3.30	0.847			2.00	0.888	4.26	0.440
0.400	0.795	3.40	0.848			2.10	0.887	4.30	0.404
0.42	0.824	3.50	0.848			2.20	0.886	4.40	0.314
0.45	0.843	3.58	0.846			2.30	0.885	4.41	0.300
0.48	0.862	3.61	0.845			2.36	0.885	4.50	0.212
0.50	0.868	3.69	0.840			2.40	0.885	4.57	0.140
0.53	0.874	3.74	0.836			2.50	0.885	4.60	0.110
0.54	0.876	3.80	0.830			2.56	0.885	4.61	0.103
0.56	0.878	3.86	0.822			2.60	0.884	4.64	0.074
0.60	0.881	3.90	0.816			2.70	0.880	4.70	0.049
0.64	0.883	3.96	0.806			2.71	0.879	4.79	0.021
0.67	0.884	4.00	0.798			2.80	0.870	4.80	0.017
0.73	0.885	4.04	0.788			2.88	0.857	4.87	0.000
0.80	0.884	4.10	0.770			2.90	0.853	4.90	0.000
0.90	0.880	4.16	0.744			2.97	0.847	5.00	0.000
1.00	0.877	4.20	0.723			3.00	0.846		
1.04	0.876	4.25	0.690			3.04	0.847		
1.10	0.875	4.30	0.653			3.10	0.851		
1.20	0.874	4.36	0.590			3.19	0.849		
1.30	0.874	4.40	0.544			3.20	0.848		
1.40	0.874	4.47	0.460			3.26	0.843		
1.50	0.874	4.50	0.410			3.30	0.838		
1.60	0.875	4.53	0.358			3.34	0.831		
1.70	0.876	4.60	0.245			3.40	0.818		
1.80	0.877	4.65	0.193			3.45	0.801		
2.00	0.878	4.69	0.148			3.50	0.791		
2.14	0.879	4.70	0.138			3.60	0.766		

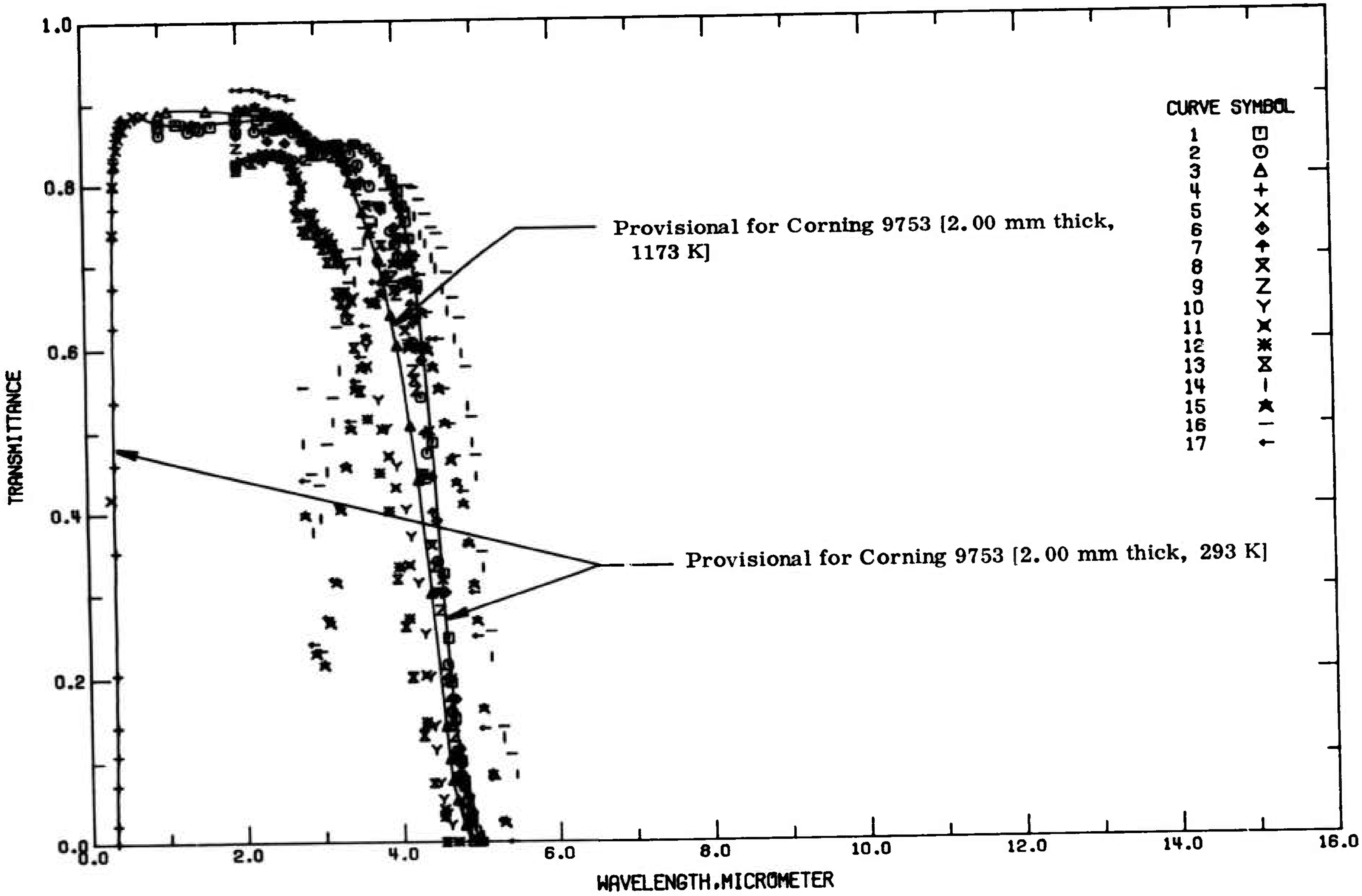


FIGURE 8-9. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE).

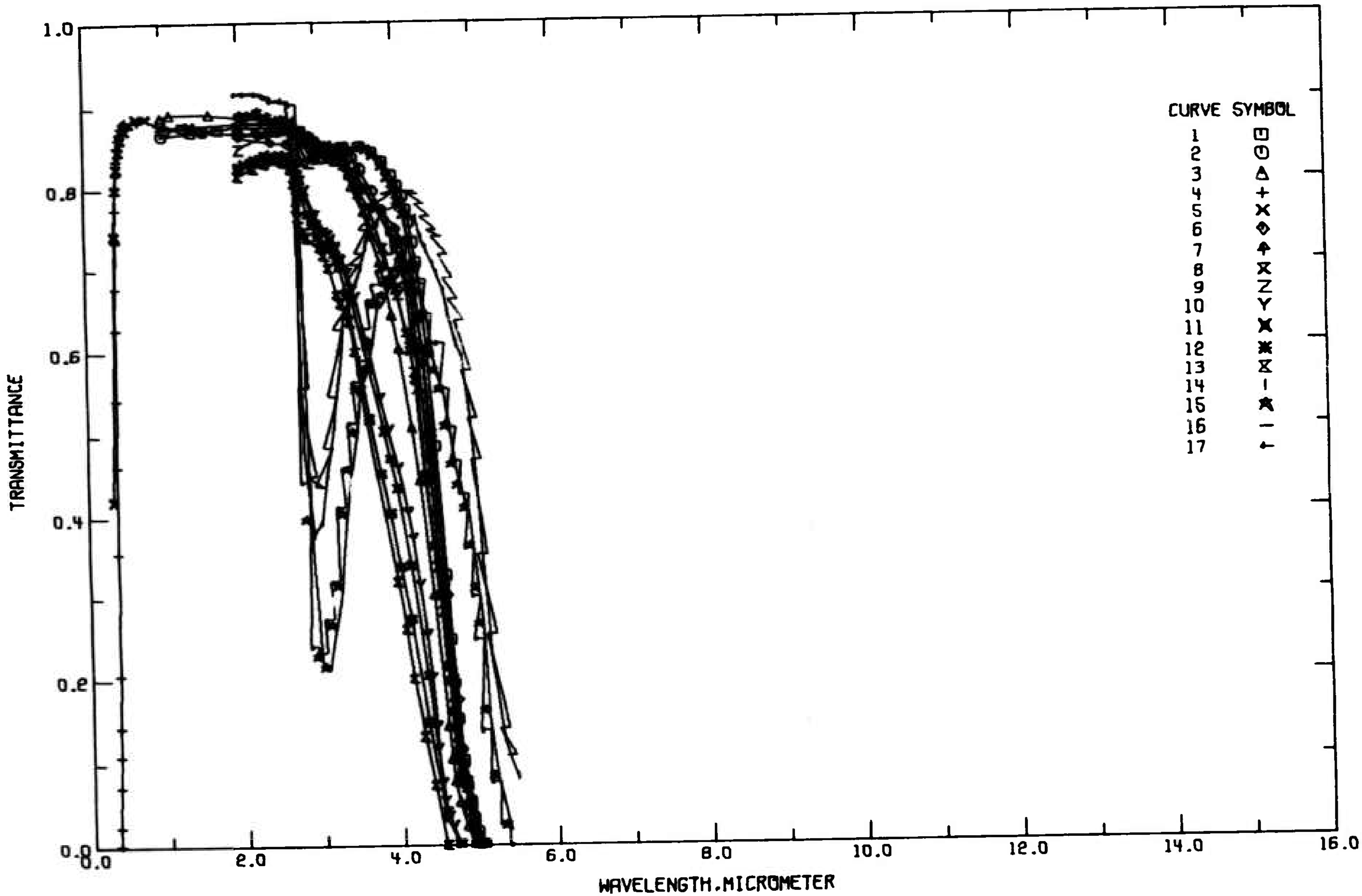


FIGURE 8-10. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE).

TABLE 8-13. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF CALCIUM ALUMINUM SILICATE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, µm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00009	Kandrach, G.S.	1975	1.0-5.0	298	Corning 9753	Specimen 2.02 mm thick; spectral transmittance; smooth values from figure.
2	A00009	Kandrach, G.S.	1975	1.0-4.9	773	Corning 9753	Similar to the above specimen.
3	A00009	Kandrach, G.S.	1975	1.0-4.9	1173	Corning 9753	Similar to the above specimen.
4	A00009	Kandrach, G.S.	1975	0.32-0.70	293	CGW-Glass 9753	Specimen 2.02 mm thick; spectral transmittance; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K.
5	A00009	Kandrach, G.S.	1975	0.31-4.7	293	Corning 9753 glass	Specimen typically 2.00 mm thick; spectral transmittance; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K.
6	A00009	Kandrach, G.S.	1975	2.0-5.0	293	Corning 9753	Specimen 0.3175 cm (1/8 in.) thick; spectral transmittance; smooth values from figure; measurement temperature specified as ambient temperature, 293 K assigned.
7	A00009	Kandrach, G.S.	1975	2.0-4.9	473	Corning 9753	Specimen 0.3175 cm (1/8 in.) thick; spectral transmittance; smooth values from figure.
8	A00009	Kandrach, G.S.	1975	2.0-4.7	673	Corning 9753	Similar to the above specimen.
9	A00009	Kandrach, G.S.	1975	2.0-4.9	873	Corning 9753	Similar to the above specimen.
10	A00009	Kandrach, G.S.	1975	2.0-4.7	293	Corning 9753	Specimen 1.27 cm (0.5 in.) thick; spectral transmittance; smooth values from figure; temperature called ambient temperature, 293 K assigned.
11	A00009	Kandrach, G.S.	1975	2.0-4.7	473	Corning 9753	Specimen 1.27 cm (0.5 in.) thick; spectral transmittance; smooth values from figure.
12	A00009	Kandrach, G.S.	1975	2.0-4.7	673	Corning 9753	Similar to the above specimen.
13	A00009	Kandrach, G.S.	1975	2.0-4.5	873	Corning 9753	Similar to the above specimen.
14	T39835	Florence, J.M., Glaze, F.W., and Black, M.H.	1955	2.0-5.5	293	C-1458	52.0 CaO, 41.2 Al_2O_3, and 6.8 SiO_2; specimen 2.18 mm thick; data from figure.
15	T39835	Florence, J.M., et al.	1955	2.0-5.3	293	C-1458	Similar to the above specimen except thickness 4.10 mm.
16	T39835	Florence, J.M., et al.	1955	2.0-5.4	293	C-1474	49.5 CaO, 43.7 Al_2O_3, and 6.8 SiO_2; specimen 2.02 mm thick; data from figure.
17	T39835	Florence, J.M., et al.	1955	2.0-5.4	293	C-1474	Similar to the above specimen except thickness 4.16 mm.

TABLE 8-14. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

CURVE 1
T = 298.

λ	τ
1.00	0.873
1.23	0.875
1.48	0.872
1.66	0.872
2.00	0.880
2.29	0.880
2.61	0.876
2.74	0.871
2.86	0.861
3.00	0.845
3.19	0.845
3.30	0.849
3.52	0.849
3.67	0.842
3.80	0.831
3.92	0.815
4.00	0.803
4.07	0.769
4.12	0.772
4.16	0.753
4.20	0.731
4.24	0.708
4.29	0.674
4.37	0.599
4.46	0.485
4.57	0.324
4.62	0.245
4.65	0.193
4.69	0.148
4.75	0.101
4.79	0.069
4.83	0.047
4.87	0.028
4.92	0.014
5.00	0.000

CURVE 2
T = 773.

λ	τ
1.00	0.862
1.38	0.866
1.53	0.868
2.00	0.866
2.24	0.865
2.53	0.870
2.65	0.870
2.74	0.864
2.97	0.834
3.05	0.834
3.23	0.844
3.33	0.844
3.45	0.836
3.56	0.822
3.71	0.796
3.96	0.741
4.02	0.724
4.06	0.706
4.12	0.676
4.22	0.605
4.31	0.542
4.38	0.472
4.49	0.339
4.60	0.214
4.65	0.155
4.70	0.112
4.76	0.070
4.81	0.037
4.89	0.000

CURVE 3
T = 1173.

λ	τ
1.00	0.887
1.11	0.891
1.62	0.891
2.36	0.885
2.56	0.885
2.71	0.879
2.80	0.870
2.88	0.857
2.97	0.847
3.04	0.847
3.19	0.849
3.26	0.843
3.34	0.831
3.45	0.801
3.60	0.766
3.69	0.739
3.79	0.707
3.85	0.681
3.94	0.640
4.02	0.602
4.17	0.506
4.26	0.440
4.41	0.300
4.57	0.140
4.61	0.103
4.64	0.074
4.70	0.049
4.79	0.021
4.87	0.000

CURVE 4
T = 293.

λ	τ
0.319	0.000
0.324	0.023
0.331	0.069
0.337	0.108
0.341	0.141
0.345	0.204
0.353	0.352
0.359	0.460
0.364	0.538
0.371	0.626
0.377	0.674
0.387	0.734
0.394	0.771
0.400	0.795
0.409	0.817
0.417	0.833
0.429	0.848
0.443	0.858
0.461	0.866
0.484	0.874
0.510	0.880
0.532	0.882
0.700	0.882

CURVE 5
T = 293.

λ	τ
0.31	0.418
0.38	0.740
0.40	0.799
0.42	0.824
0.45	0.843
0.48	0.856
0.53	0.869
0.59	0.879
0.68	0.886
0.81	0.886
1.00	0.875
1.38	0.875
2.68	0.882
2.81	0.829
3.31	0.847
3.54	0.847
3.64	0.844
3.72	0.837
3.83	0.825
3.90	0.812
3.97	0.797
4.03	0.782
4.10	0.763
4.17	0.732
4.21	0.699
4.32	0.600
4.42	0.500
4.55	0.317
4.64	0.198
4.74	0.090

CURVE 6
T = 293.

λ	τ
2.00	0.861
2.41	0.854
2.63	0.851
2.83	0.853
3.01	0.845
3.28	0.836
3.36	0.831
3.59	0.801
3.83	0.770
4.01	0.746
4.07	0.733
4.15	0.702
4.27	0.636
4.33	0.564
4.39	0.498
4.44	0.444
4.49	0.389
4.59	0.301
4.70	0.172
4.74	0.115
4.76	0.096
4.79	0.079
4.84	0.054
4.88	0.035
5.00	0.000

CURVE 7
T = 473.

λ	τ
2.00	0.861
2.36	0.865
2.46	0.868
2.59	0.858
2.83	0.854
2.91	0.862
3.01	0.854
3.12	0.848
3.23	0.844
3.31	0.844
3.41	0.814
3.54	0.814
4.01	0.725
4.05	0.711
4.10	0.698
4.15	0.678
4.20	0.652
4.23	0.629
4.26	0.598
4.35	0.496
4.44	0.399
4.53	0.299
4.64	0.173
4.67	0.141
4.72	0.102
4.78	0.061
4.84	0.026
4.90	0.000

CURVE 8
T = 673.

λ	τ
2.00	0.874
2.70	0.873
2.79	0.866
2.93	0.852
3.01	0.844
3.20	0.842
3.29	0.839
3.35	0.834
3.41	0.824
3.54	0.798
3.66	0.773

TABLE 8-14. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 8(CONT.)	
3.84	0.723
4.00	0.669
4.13	0.620
4.17	0.593
4.23	0.562
4.33	0.447
4.42	0.359
4.49	0.300
4.59	0.194
4.67	0.106
4.69	0.079
CURVE 9	
T = 873.	
2.00	0.845
2.48	0.868
2.69	0.871
2.90	0.829
3.01	0.835
3.17	0.835
3.24	0.832
3.35	0.827
3.42	0.816
3.53	0.792
3.70	0.745
3.96	0.685
4.02	0.664
4.16	0.603
4.22	0.572
4.25	0.550
4.35	0.442
4.46	0.333
4.52	0.279
4.59	0.203
4.63	0.164
4.67	0.129
4.71	0.103
4.77	0.072
4.83	0.046

λ	τ
CURVE 9(CONT.)	
4.94	0.000
CURVE 10	
T = 293.	
2.00	0.823
2.36	0.826
2.60	0.830
2.66	0.827
2.70	0.821
2.74	0.814
2.84	0.797
2.97	0.763
3.13	0.739
3.22	0.726
3.29	0.711
3.37	0.694
3.47	0.661
3.63	0.631
3.77	0.539
3.87	0.503
3.99	0.457
4.10	0.433
4.16	0.370
4.24	0.313
4.32	0.250
4.37	0.200
4.42	0.140
4.43	0.114
4.48	0.072
4.51	0.050
4.56	0.033
4.61	0.021
4.66	0.000
CURVE 11	
T = 473.	
2.00	0.821
2.07	0.828

λ	τ
CURVE 11(CONT.)	
2.21	0.833
2.34	0.838
2.53	0.838
2.58	0.835
2.65	0.831
2.71	0.822
2.78	0.809
2.83	0.796
2.94	0.766
2.99	0.752
3.08	0.742
3.17	0.734
3.22	0.725
3.27	0.713
3.33	0.700
3.44	0.657
3.63	0.577
3.81	0.502
3.89	0.459
3.97	0.431
4.13	0.335
4.32	0.202
4.53	0.038
4.70	0.000
CURVE 12	
T = 673.	
2.00	0.824
2.28	0.833
2.40	0.835
2.53	0.835
2.63	0.832
2.69	0.821
2.76	0.804
2.81	0.786
2.88	0.764
2.94	0.751
3.01	0.738
3.12	0.728

λ	τ
CURVE 12(CONT.)	
3.21	0.719
3.25	0.712
3.28	0.701
3.36	0.667
3.63	0.515
3.77	0.449
3.88	0.401
4.00	0.333
4.12	0.269
4.32	0.144
4.53	0.031
4.69	0.000
CURVE 13	
T = 873.	
2.00	0.816
2.20	0.825
2.34	0.831
2.49	0.835
2.58	0.832
2.68	0.824
2.71	0.806
2.75	0.774
2.77	0.761
2.83	0.743
2.88	0.738
3.04	0.727
3.09	0.718
3.15	0.702
3.26	0.666
3.31	0.655
3.37	0.646
3.41	0.635
3.47	0.600
3.54	0.550
3.97	0.318
4.07	0.259
4.15	0.200
4.28	0.130

λ	τ
CURVE 13(CONT.)	
4.40	0.071
4.54	0.000
CURVE 14	
T = 293.	
2.03	0.892
2.13	0.892
2.26	0.896
2.39	0.890
2.50	0.885
2.60	0.885
2.70	0.873
2.79	0.485
2.90	0.376
3.00	0.393
3.09	0.451
3.18	0.512
3.27	0.573
3.32	0.636
3.40	0.655
3.49	0.680
3.56	0.703
3.62	0.728
3.69	0.745
3.78	0.753
3.84	0.768
3.89	0.770
4.02	0.775
4.12	0.775
4.20	0.766
4.27	0.760
4.34	0.736
4.40	0.725
4.48	0.706
4.53	0.694
4.61	0.670
4.67	0.644
4.76	0.619
4.84	0.592

λ	τ
CURVE 14(CONT.)	
4.91	0.531
4.96	0.485
5.00	0.444
5.07	0.331
5.16	0.223
5.30	0.127
5.46	0.082
CURVE 15	
T = 293.	
2.03	0.892
2.13	0.892
2.26	0.895
2.39	0.893
2.50	0.885
2.60	0.885
2.70	0.873
2.80	0.397
2.91	0.228
3.01	0.215
3.10	0.264
3.19	0.314
3.26	0.403
3.34	0.457
3.41	0.503
3.47	0.552
3.55	0.576
3.63	0.612
3.71	0.655
3.75	0.655
3.82	0.655
3.89	0.667
4.00	0.700
4.12	0.700
4.18	0.680
4.25	0.671
4.34	0.643
4.41	0.597
4.47	0.576

TABLE 8-14. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF CALCIUM ALUMINUM SILICATE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ
URVE 15(CONT.)		CURVE 16(CONT.)		CURVE 17(CONT.)	
4.54	0.552	4.25	0.794	3.82	0.698
4.61	0.510	4.33	0.780	3.91	0.718
4.68	0.464	4.40	0.763	4.02	0.736
4.75	0.437	4.48	0.746	4.10	0.736
4.83	0.410	4.54	0.738	4.18	0.709
4.89	0.362	4.62	0.719	4.26	0.709
4.95	0.311	4.67	0.689	4.33	0.687
4.99	0.266	4.74	0.660	4.40	0.643
5.05	0.160	4.82	0.636	4.47	0.610
5.15	0.084	4.89	0.576	4.55	0.610
5.30	0.024	4.96	0.518	4.61	0.552
		5.00	0.470	4.68	0.509
URVE 16		5.06	0.351	4.74	0.469
= 293.		5.16	0.253	4.83	0.426
		5.30	0.139	4.89	0.359
2.00	0.917	5.39	0.109	4.96	0.301
2.11	0.917			4.99	0.247
2.26	0.917	CURVE 17		5.06	0.137
2.37	0.914	T = 293.		5.17	0.076
2.46	0.909			5.28	0.026
2.60	0.909	2.00	0.917	5.40	0.000
2.70	0.904	2.11	0.917		
2.80	0.554	2.26	0.917		
2.89	0.449	2.37	0.914		
2.99	0.435	2.46	0.909		
3.10	0.484	2.60	0.909		
3.18	0.543	2.70	0.904		
3.25	0.626	2.80	0.441		
3.33	0.649	2.88	0.239		
3.41	0.679	2.98	0.231		
3.48	0.706	3.07	0.271		
3.54	0.719	3.16	0.318		
3.61	0.746	3.25	0.410		
3.68	0.763	3.33	0.458		
3.75	0.774	3.41	0.513		
3.81	0.777	3.48	0.561		
3.90	0.792	3.55	0.589		
4.00	0.797	3.61	0.627		
4.10	0.797	3.68	0.658		
4.19	0.797	3.75	0.679		

g. Normal Spectral Transmittance (Temperature Dependence)

There are 10 sets of experimental data available for the temperature dependence of the normal spectral transmittance of calcium aluminum silicate all of which apply to Corning 9753. The data is listed in Table 8-17 and shown in Figures 8-11 and 8-12. Specimen characterization and measurement information for the data are given in Table 8-16.

The 10 data sets are all for a thickness of 2 mm and cover a wavelength range of 3.5 to 4.7 μm. The temperature range covered is from slightly over 300 K to about 1175 K which is above the strain point (1073 K) but below the melting range (1723 to 1773 K).

A provisional curve is given for Corning 9753 at a wavelength of 3.8 μm. The provisional values are listed in Table 8-15 and shown in Figure 8-11. The provisional values were obtained by using linear interpolation between the 3.75 μm data (curve number 2 in Tables 8-16 and 8-17) and the 4.0 μm data (curve number 3 in Tables 8-16 and 8-17). Values of transmittance were read for the same values of temperatures and then linear interpolation performed. The uncertainty of the provisional values are no larger than 15%.

TABLE 8-15. PROVISIONAL NORMAL TRANSMITTANCE OF CALCIUM ALUMINUM SILICATE(CORNING 9753) (TEMPERATURE DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

T	τ
2MM THICK	
λ = 3.8	
310.	0.821
323.	0.819
373.	0.815
400.	0.814
473.	0.811
500.	0.808
573.	0.832
600.	0.798
673.	0.792
700.	0.788
773.	0.779
800.	0.774
873.	0.761
900.	0.756
973.	0.744
1000.	0.739
1073.	0.727
1100.	0.720
1173.	0.701

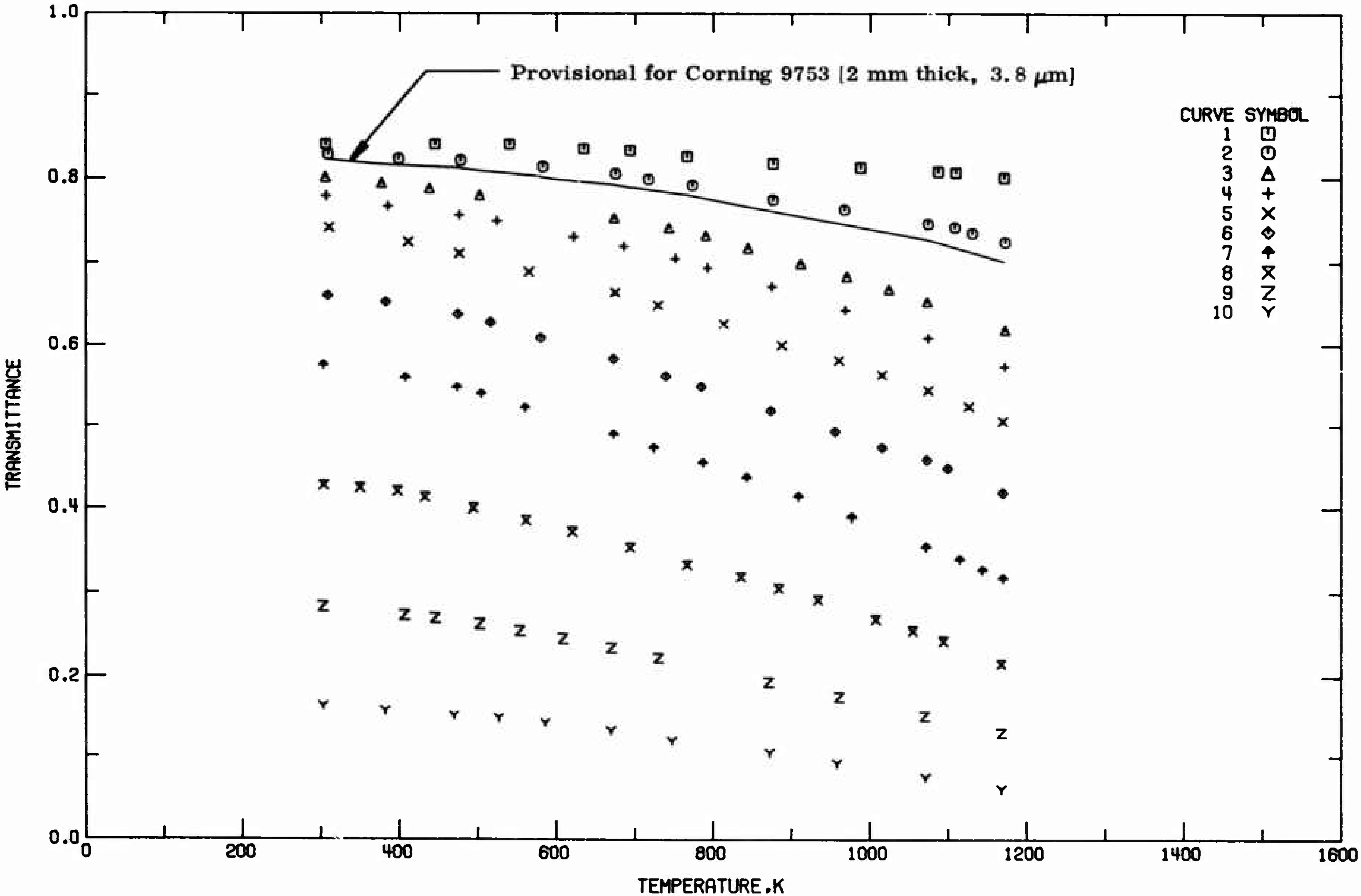


FIGURE 8-11. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF CALCIUM ALUMINUM SILICATE (TEMPERATURE DEPENDENCE).

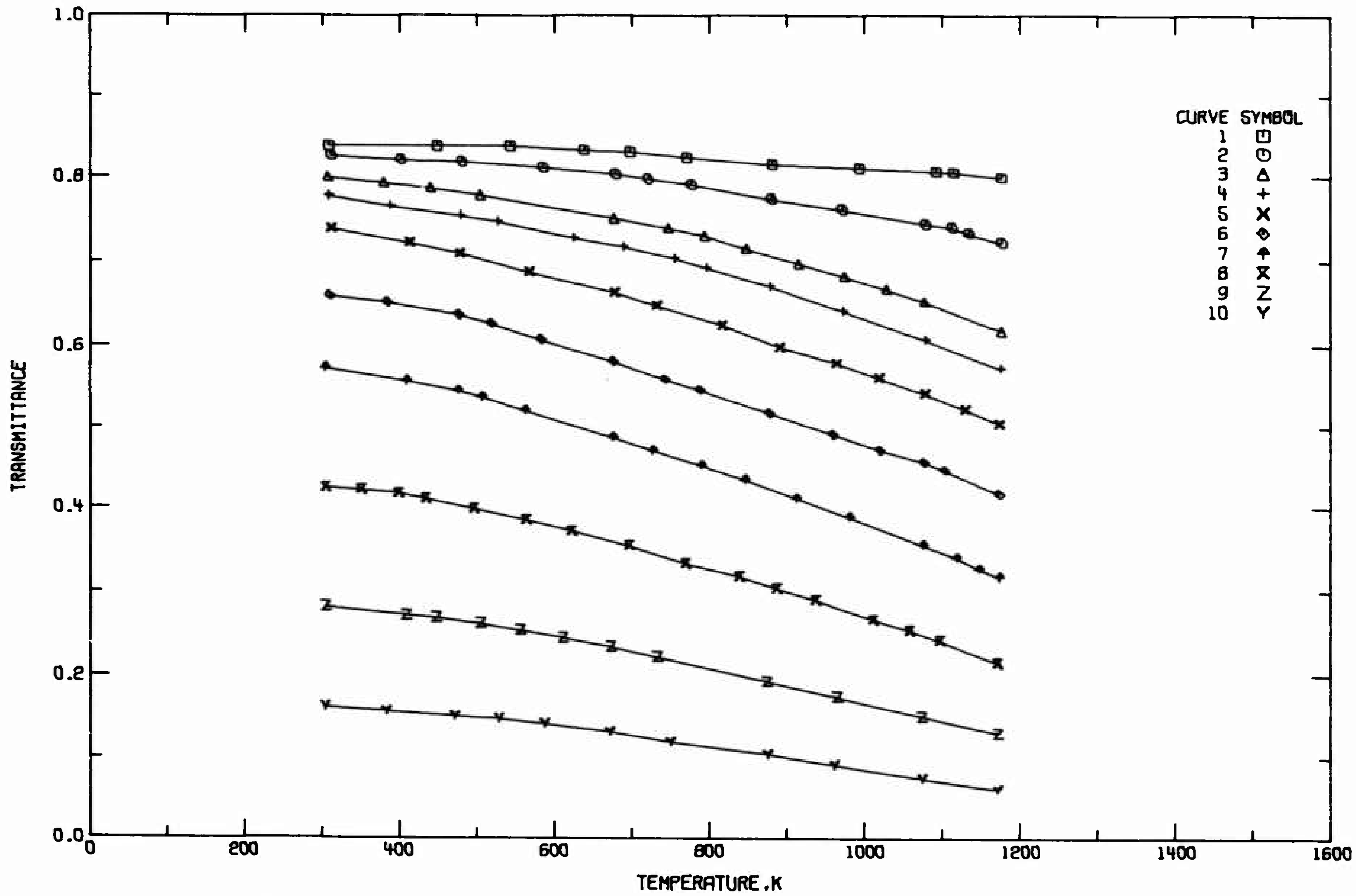


FIGURE 8-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF CALCIUM ALUMINUM SILICATE (TEMPERATURE DEPENDENCE).

TABLE 8-16. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF CALCIUM ALUMINUM SILICATE (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00009	Kandrach, G.S.	1975	3.5	307-1174	Code 9753	Specimen 2 mm thick; smooth values from figure; additional information supplied by Corning Glass Works.
2	A00009	Kandrach, G.S.	1975	3.75	310-1174	Code 9753	Similar to the above specimen.
3	A00009	Kandrach, G.S.	1975	4.0	306-1174	Code 9753	Similar to the above specimen.
4	A00009	Kandrach, G.S.	1975	4.1	307-1173	Code 9753	Similar to the above specimen.
5	A00009	Kandrach, G.S.	1975	4.2	311-1171	Code 9753	Similar to the above specimen.
6	A00009	Kandrach, G.S.	1975	4.3	309-1171	Code 9753	Similar to the above specimen.
7	A00009	Kandrach, G.S.	1975	4.4	303-1171	Code 9753	Similar to the above specimen.
8	A00009	Kandrach, G.S.	1975	4.5	304-1169	Code 9753	Similar to the above specimen.
9	A00009	Kandrach, G.S.	1975	4.6	303-1169	Code 9753	Similar to the above specimen.
10	A00009	Kandrach, G.S.	1975	4.7	303-1169	Code 9753	Similar to the above specimen.

TABLE 8-17. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF CALCIUM ALUMINUM SILICATE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

T	τ
CURVE 1, λ = 3.5	
307.	0.838
447.	0.838
542.	0.838
637.	0.833
696.	0.831
769.	0.824
879.	0.816
991.	0.811
1090.	0.807
1112.	0.806
1174.	0.800
CURVE 2, λ = 3.75	
310.	0.826
430.	0.821
479.	0.819
584.	0.812
677.	0.804
719.	0.798
775.	0.791
878.	0.774
969.	0.762
1076.	0.745
1110.	0.741
1132.	0.734
1174.	0.723
CURVE 3, λ = 4.0	
306.	0.800
378.	0.793
439.	0.787
503.	0.779
675.	0.752
745.	0.743
792.	0.731
CURVE 3 (CONT.)	
846.	0.716
913.	0.698
972.	0.683
1026.	0.668
1075.	0.653
1174.	0.618
CURVE 4, λ = 4.1	
307.	0.778
386.	0.766
477.	0.755
525.	0.748
623.	0.729
687.	0.716
753.	0.704
794.	0.693
876.	0.671
970.	0.642
1076.	0.608
1173.	0.573
CURVE 5, λ = 4.2	
311.	0.740
412.	0.723
477.	0.710
566.	0.688
676.	0.664
731.	0.648
815.	0.625
889.	0.599
962.	0.580
1017.	0.562
1076.	0.543
1128.	0.523
1171.	0.505
CURVE 6, λ = 4.3	
309.	0.660
383.	0.652
475.	0.637
517.	0.627
531.	0.608
674.	0.582
741.	0.565
786.	0.547
875.	0.518
957.	0.492
1017.	0.472
1074.	0.457
1101.	0.447
1171.	0.417
CURVE 7, λ = 4.4	
303.	0.574
408.	0.558
474.	0.546
505.	0.538
561.	0.521
674.	0.488
725.	0.471
788.	0.453
844.	0.435
910.	0.412
978.	0.389
1073.	0.355
1116.	0.340
1145.	0.327
1171.	0.317
CURVE 8, λ = 4.5	
304.	0.425
350.	0.422
CURVE 8 (CONT.)	
398.	0.418
433.	0.411
495.	0.399
562.	0.385
621.	0.372
695.	0.354
768.	0.333
837.	0.318
885.	0.304
935.	0.290
1009.	0.267
1056.	0.254
1095.	0.242
1169.	0.215
CURVE 9, λ = 4.6	
303.	0.282
407.	0.272
446.	0.269
503.	0.262
554.	0.254
609.	0.245
671.	0.234
731.	0.222
872.	0.193
962.	0.175
1071.	0.151
1169.	0.130
CURVE 10, λ = 4.7	
303.	0.163
352.	0.157
470.	0.151
527.	0.148
586.	0.142
670.	0.132
CURVE 10 (CONT.)	
748.	0.119
873.	0.104
959.	0.091
1072.	0.074
1169.	0.060

4.9. Magnesium Fluoride

Since data evaluation was asked to be carried out on the specific kind of magnesium fluoride known as Irtran 1, the treatment in this section will concentrate on that material.

Irtran 1, produced by the Eastman Kodak Company, is a hot-pressed, polycrystalline solid of magnesium fluoride, MgF_2. The word "Irtran" is a trademark of the Eastman Kodak Company. Because it is polycrystalline it does not exhibit cleavage. The visual appearance of Irtran 1 is transparent in colors ranging from tan to green [E62600]. According to Kodak [E62600], the long-range infrared cut-off frequency is approximately 7.5 μm for a 2 mm thick specimen for which the transmittance is 10%. It has a Knoop hardness of 576 and is approximately as hard as soft steel. The density is 3.18 g cm^{-3} at 298 K. Other physical properties include a modulus of rupture of 21,800 psi at 298 K, and an expansion coefficient of 11.0×10^{-6} C^{-1} between 298 and 473 K. It is insoluble in water and there is no change in transmittance or weight upon both inorganic and organic chemical immersion. It has a melting point of 1528 K [T39947] and a high thermal shock resistance. It is used as windows, domes, prisms, and filter substrates for infrared systems.

a. Normal Spectral Emittance (Wavelength Dependence)

A total of 20 sets of experimental data were located for the wavelength dependence of the normal spectral emittance of Irtran 1. The data are listed in Table 9-3 and shown in Figures 9-1 and 9-2. Specimen characterization and measurement information for the data are given in Table 9-2.

Numerical values of the data are low at 4.5 μm, being less than 0.16 and above 5.5 μm they increase sharply such that above 10 μm all the data are above 0.75. There is a conflicting element in the data. Stierwalt, et al. [T33450] presented data for a 2 mm thick specimen at 333 K (curve 17), 393 K (curve 18), and 453 K (curve 19). Above 10 μm the values of the normal spectral emittance for these curves are between 0.75 and 0.90. Hatch [T76525] presented an argument that the emittance for specimen thicknesses of 1 mm or greater should be greater than 0.99 from 293 to 970 K and between 10 and 15 μm. The argument of Hatch and the data of Stierwalt, et al. are incompatible. As a consequence it was decided to consider evaluated data only within a restricted wavelength range of 3 to 6.4 μm.

Provisional values for a 2 mm thick specimen at a temperature of 293 K for a wavelength region of 3 to 6.4 μm are listed in Table 9-1 and shown in Figure 9-1. These values were generated by using the Kodak scheme, Eqs. (2.6-13) and (2.6-15), for

calculating emittance from transmittance and refractive index data. The transmittance data used was data from curve 22 in Tables 9-17 and 9-18. The refractive index data used was taken from the data of curve 2 in Tables 9-4 and 9-5. The refractive index data is shown in Figure 9-3. Provisional values for a specimen thickness of 3.8 mm at a temperature of 589 K for a wavelength range of 3 to 6.4 μm are given, as well as a set of provisional values for a thickness of 3.8 mm, a temperature of 970 K, and a wavelength range of 3 to 6.0 μm. The provisional values for 589 K are based on curve 8 while those for 970 K are based on curve 11. The values are listed in Table 9-1 and shown in Figure 9-1. Because of the low value of emittance, the uncertainty for all three provisional curves can be as high as 25%.

TABLE 9-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF MAGNESIUM FLUORIDE(IRTRAN 1) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε
2MM THICK		3.8MM THICK		3.8MM THICK	
T = 293		T = 589		T = 973	
3.00	0.089	3.0	0.154	3.0	0.177
3.03	0.085	3.11	0.124	3.07	0.155
3.10	0.079	3.24	0.102	3.31	0.109
3.19	0.074	3.42	0.076	3.56	0.083
3.27	0.069	3.80	0.053	3.80	0.071
3.38	0.065	4.0	0.048	4.0	0.070
3.49	0.060	4.14	0.045	4.42	0.066
3.80	0.060	4.64	0.045	4.81	0.076
3.98	0.059	4.97	0.052	4.98	0.081
4.00	0.060	5.0	0.054	5.0	0.084
4.46	0.060	5.09	0.061	5.23	0.111
4.68	0.060	5.25	0.078	5.47	0.094
4.78	0.057	5.46	0.062	5.65	0.111
4.88	0.052	5.60	[illegible]	5.84	0.154
4.95	0.058	5.79	0.077	6.00	0.187
5.00	0.057	6.0	0.107		
5.01	0.058	6.01	0.108		
5.13	0.050	6.20	0.145		
5.23	0.046	6.35	0.185		
5.32	0.044	6.4	0.197		
5.59	0.045				
5.69	0.050				
5.79	0.054				
5.87	0.060				
6.00	0.071				
6.16	0.087				
6.34	0.109				
6.40	0.118				

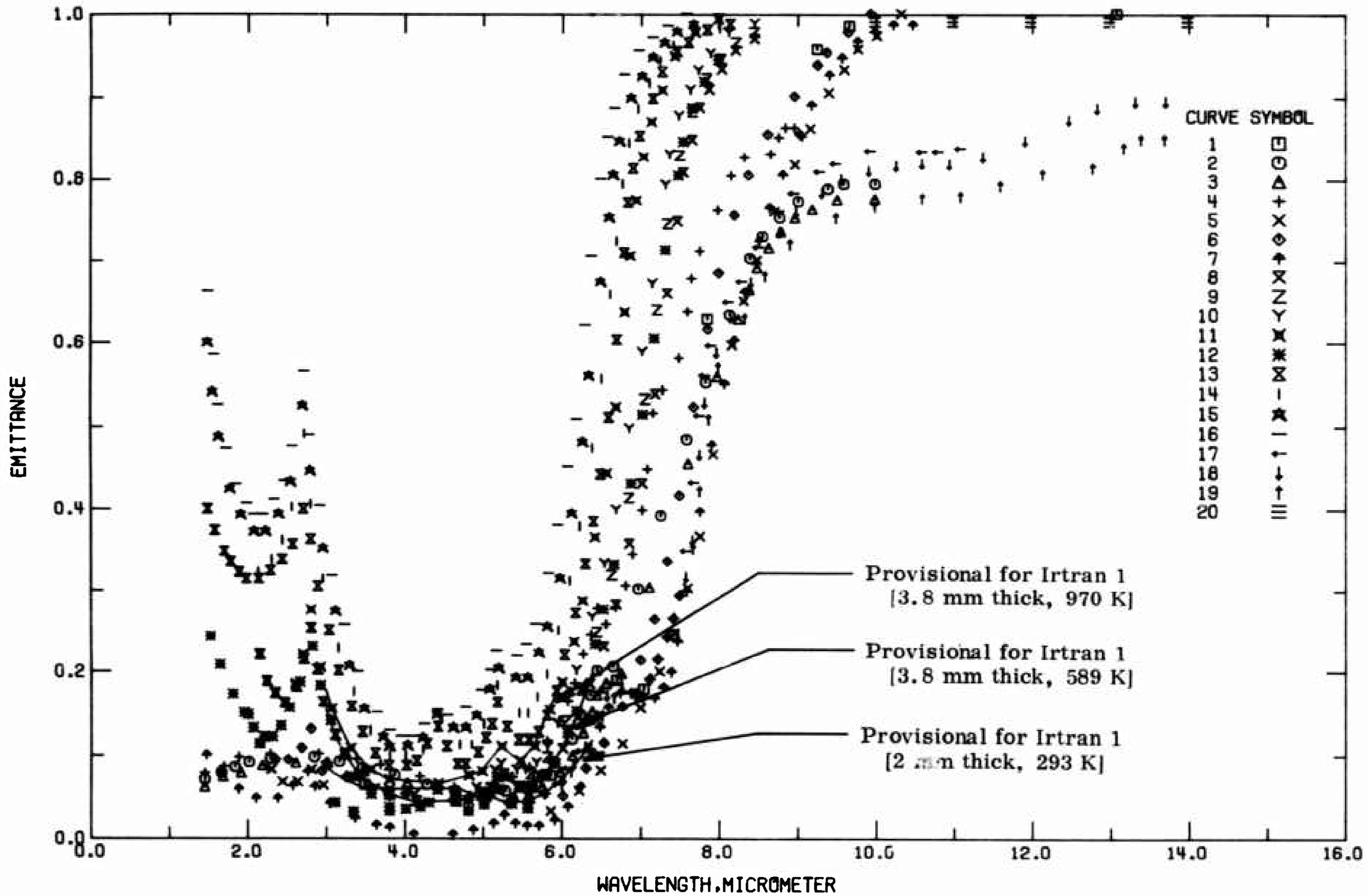


FIGURE 9-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE).

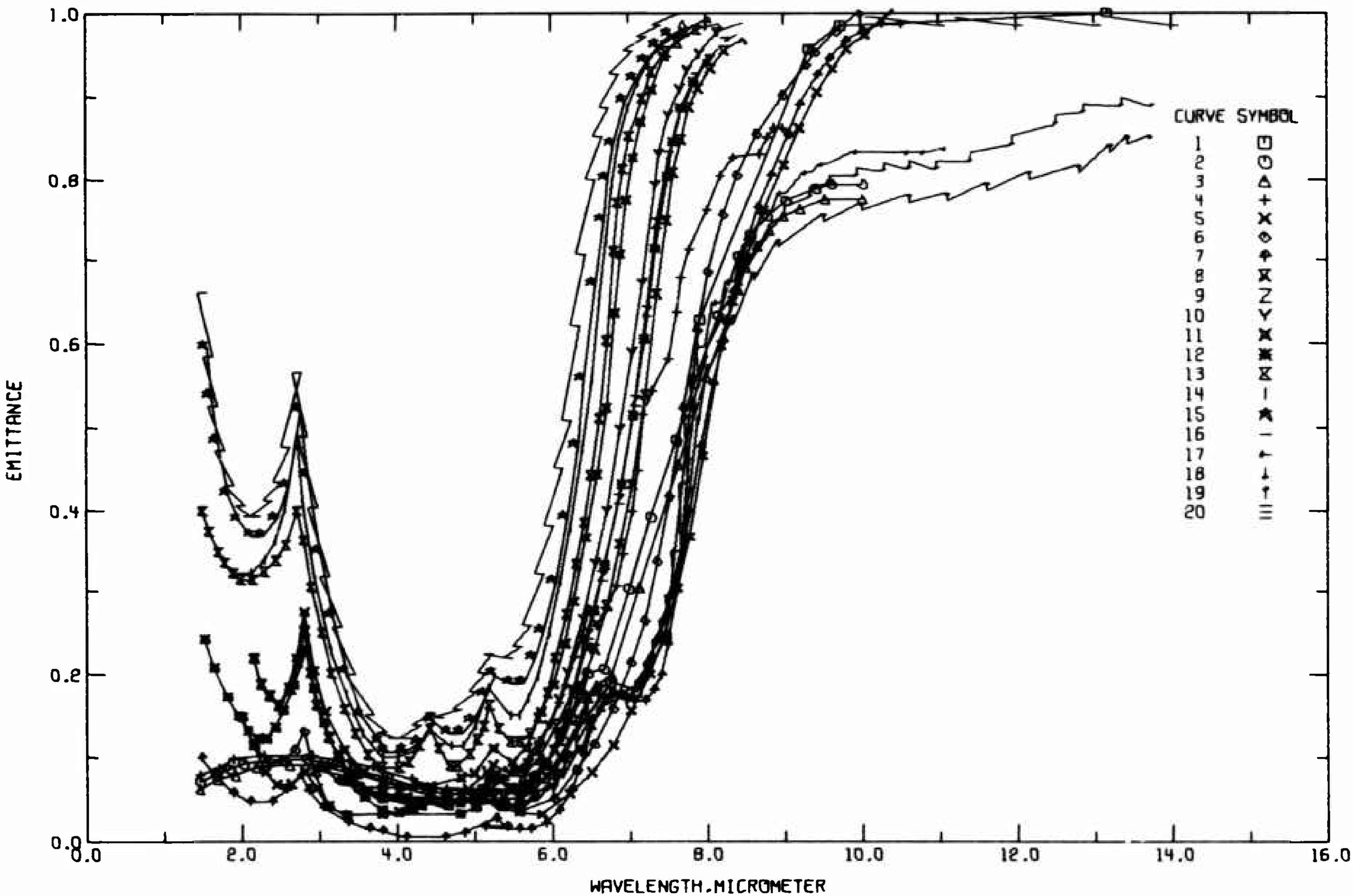


FIGURE 9-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE).

TABLE 9-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF MAGNESIUM FLUORIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T39952	Stierwalt, D. L.	1966	3.5-45	77	Irtran 1	Sample 2.0 mm thick; material from Eastman Kodak Co.; smooth values from figure; $\theta' = 0°$.
2	T17017	Ballard, S. S., McCarthy, K. A., and Wolfe, W. L.	1961	1.5-10	673	Irtran 1	Specimen thickness 1.75 mm; emissivity; information in this reference was obtained from Eastman Kodak Co. sales literature dated 15 June 1959 and 23 February 1961; $\theta' = 0°$.
3	T17017	Ballard, S. S., et al.	1961	1.5-10	873	Irtran 1	Similar to the above specimen.
4	T17017	Ballard, S. S., et al.	1961	1.5-9.1	1073	Irtran 1	Similar to the above specimen.
5	T76525	Hatch, S. E.	1962	2.0-10	647	Irtran 1	Specimen 1 mm thick; specimen holder uncoated stainless steel; smooth values from figure.
6	T76525	Hatch, S. E.	1962	2.0-10	865	Irtran 1	The above specimen.
7	T76525	Hatch, S. E.	1962	1.5-10	647	Irtran 1	The above specimen except specimen holder gold plated.
8	T76525	Hatch, S. E.	1962	2.2-8.5	589	Irtran 1	Specimen 3.8 mm thick; specimen holder uncoated stainless steel; smooth values from figure.
9	T76525	Hatch, S. E.	1962	2.2-8.5	647	Irtran 1	The above specimen.
10	T76525	Hatch, S. E.	1962	2.2-8.5	865	Irtran 1	The above specimen.
11	T76525	Hatch, S. E.	1962	2.2-8.0	970	Irtran 1	The above specimen.
12	T76525	Hatch, S. E.	1962	1.5-8.0	647	Irtran 1	The above specimen except specimen holder gold plated.
13	T76525	Hatch, S. E.	1962	1.5-8.2	594	Irtran 1	Specimen 7.6 mm thick; specimen holder uncoated stainless steel; smooth values from figure.
14	T76525	Hatch, S. E.	1962	1.5-8.0	647	Irtran 1	The above specimen.
15	T76525	Hatch, S. E.	1962	1.5-7.7	865	Irtran 1	The above specimen.
16	T76525	Hatch, S. E.	1962	1.5-8.0	970	Irtran 1	The above specimen.
17	T33450	Stierwalt, D. L., Kirk, D. D., and Bernstein, J. B.	1963	3.0-11	333	Irtran 1	Specimen 2 mm thick; smooth values from figure.
18	T33450	Stierwalt, D. L., et al.	1963	3.0-15	393	Irtran 1	Similar to the above specimen.
19	T33450	Stierwalt, D. L., et al.	1963	3.0-15	453	Irtran 1	Similar to the above specimen.
20	T76525	Hatch, S. E.	1962	10-15	293	Irtran 1	Thickness 1 mm or greater; argument given on p. 597 of this reference that emittance between 10 and 15 μ is greater than 0.99 from ambient temperature, 293 K assigned, to 970 K; $\theta' = 0°$.

TABLE 9-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 1	
T = 77.	
3.49	0.065
5.52	0.062
5.86	0.076
6.71	0.190
7.05	0.179
7.43	0.245
7.87	0.528
9.27	0.957
9.68	0.985
13.1	1.00
14.3	1.00
15.1	0.943
15.6	0.862
16.0	0.411
16.4	0.267
16.8	0.114
20.5	0.080
21.2	0.101
21.7	0.152
22.2	0.233
22.7	0.585
23.1	0.690
23.6	0.713
24.4	0.572
25.2	0.588
26.0	0.716
26.6	0.784
27.6	0.838
29.8	0.917
32.1	0.979
33.0	0.987
33.8	0.971
35.3	0.797
38.0	0.667
39.4	0.536
39.8	0.252
41.6	0.588
42.7	0.627
44.5	0.645
CURVE 2	
T = 673.	
1.45	0.071
1.66	0.079
1.83	0.086
2.01	0.092
2.28	0.096
2.84	0.098
3.16	0.093
3.45	0.085
3.86	0.077
4.27	0.065
4.63	0.057
5.27	0.057
5.56	0.059
5.69	0.074
5.89	0.093
6.12	0.120
6.23	0.145
6.36	0.172
6.44	0.201
6.65	0.236
6.97	0.302
7.26	0.392
7.59	0.465
7.83	0.552
8.14	0.633
8.40	0.703
8.56	0.730
8.78	0.753
9.02	0.773
9.40	0.788
9.60	0.794
10.00	0.794
CURVE 3	
T = 873.	
1.45	0.052
1.68	0.074
1.91	0.079
CURVE 3 (CONT.)	
2.18	0.088
2.61	0.091
3.01	0.091
3.47	0.081
4.02	0.067
4.64	0.050
5.38	0.050
5.57	0.052
5.74	0.052
5.97	0.080
6.13	0.100
6.27	0.127
6.38	0.152
6.44	0.172
6.56	0.186
6.75	0.198
7.11	0.304
7.61	0.456
7.98	0.559
8.25	0.628
8.39	0.664
8.49	0.691
8.64	0.716
8.80	0.736
8.98	0.753
9.20	0.763
9.52	0.775
10.00	0.776
CURVE 4	
T = 1073.	
1.45	0.079
1.69	0.087
1.88	0.098
2.28	0.102
2.90	0.102
3.38	0.096
3.68	0.089
4.18	0.075
CURVE 4 (CONT.)	
4.62	0.062
5.17	0.062
5.36	0.074
5.58	0.086
5.81	0.118
5.96	0.140
6.07	0.165
6.15	0.186
6.27	0.221
6.37	0.245
6.45	0.278
6.56	0.258
6.68	0.279
6.81	0.306
6.90	0.345
7.02	0.399
7.09	0.449
7.16	0.515
7.28	0.543
7.49	0.581
7.60	0.637
7.65	0.678
7.76	0.712
7.99	0.762
8.16	0.804
8.33	0.827
8.67	0.831
8.77	0.851
8.86	0.863
8.97	0.863
9.07	0.853
CURVE 5	
T = 647.	
2.00	0.148
2.15	0.114
2.30	0.063
2.44	0.063
2.63	0.068
CURVE 5 (CONT.)	
2.81	0.083
2.96	0.064
3.11	0.043
3.34	0.032
3.80	0.033
4.80	0.033
5.00	0.041
5.19	0.059
5.35	0.042
5.56	0.036
5.85	0.033
6.21	0.057
6.49	0.082
6.77	0.114
7.00	0.156
7.24	0.200
7.43	0.247
7.60	0.303
7.76	0.367
7.93	0.467
8.17	0.597
8.32	0.650
8.49	0.701
8.72	0.761
8.98	0.818
9.18	0.862
9.41	0.905
9.61	0.933
9.79	0.957
10.03	0.973
10.34	1.000
CURVE 6	
T = 865.	
2.00	0.148
2.15	0.114
2.35	0.095
2.51	0.095
2.68	0.109
CURVE 6 (CONT.)	
2.80	0.131
2.94	0.051
3.11	0.043
3.34	0.032
3.80	0.033
4.80	0.033
5.00	0.041
5.19	0.059
5.35	0.042
5.55	0.036
6.01	0.051
6.30	0.035
6.53	0.115
6.77	0.158
7.00	0.214
7.18	0.264
7.34	0.336
7.50	0.417
7.68	0.522
7.86	0.616
8.00	0.685
8.20	0.756
8.38	0.835
8.63	0.855
8.97	0.901
9.27	0.938
9.39	0.953
9.66	0.977
9.95	1.000
CURVE 7	
T = 647.	
1.47	0.100
1.65	0.079
1.88	0.059
2.10	0.048
2.38	0.048
2.57	0.063
2.76	0.060

TABLE 9-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE	7(CONT.)	CURVE	7(CONT.)	CURVE	8(CONT.)	CURVE	9(CONT.)	CURVE	10(CONT.)	CURVE	11(CONT.)
2.85	0.062	10.00	0.977	7.76	0.887	8.03	0.945	7.37	0.831	7.14	0.870
3.04	0.042	10.24	0.986	7.88	0.909	8.23	0.965	7.49	0.878	7.28	0.908
3.36	0.024	10.49	0.986	8.04	0.933	8.46	0.977	7.64	0.909	7.44	0.948
3.63	0.016			8.22	0.955			7.74	0.932	7.70	0.977
3.80	0.013	CURVE 8		8.46	0.969	CURVE 10		7.90	0.952	8.00	0.993
4.10	0.005	T = 589.				T = 865.		8.13	0.977		
4.60	0.005			CURVE 9				8.46	0.988	CURVE 12	
4.86	0.013	2.15	0.220	T = 647.		2.15	0.220			T = 647.	
5.26	0.028	2.24	0.188			2.24	0.188	CURVE 11			
5.40	0.018	2.35	0.174	2.15	0.220	2.35	0.174	T = 970.		1.52	0.242
5.12	0.018	2.47	0.162	2.24	0.188	2.47	0.162			1.64	0.208
5.55	0.015	2.62	0.182	2.35	0.174	2.62	0.182	2.15	0.220	1.81	0.173
5.70	0.015	2.71	0.215	2.47	0.162	2.71	0.215	2.24	0.135	1.95	0.150
5.90	0.022	2.80	0.253	2.62	0.182	2.80	0.253	2.35	0.174	2.07	0.132
6.07	0.038	2.88	0.202	2.71	0.215	2.88	0.202	2.47	0.162	2.21	0.122
6.23	0.062	2.96	0.163	2.80	0.253	2.96	0.163	2.60	0.185	2.31	0.122
6.39	0.153	3.11	0.124	2.88	0.202	3.11	0.124	2.70	0.220	2.42	0.135
6.48	0.133	3.24	0.102	2.96	0.163	3.24	0.102	2.80	0.275	2.5[illegible]	0.156
6.59	0.156	3.42	0.076	3.11	0.124	3.42	0.076	2.92	0.205	2.66	0.187
6.74	0.174	3.80	0.053	3.24	0.102	3.61	0.060	3.07	0.155	2.82	0.230
6.88	0.174	4.14	0.045	3.42	0.076	3.80	0.059	3.31	0.109	2.92	0.183
7.03	0.168	4.64	0.045	3.80	0.053	4.11	0.053	3.56	0.033	3.05	0.141
7.18	0.168	4.97	0.052	4.14	0.045	4.62	0.053	3.80	0.071	3.23	0.101
7.29	0.181	5.09	0.061	4.64	0.045	4.90	0.062	4.42	0.066	3.36	0.074
7.39	0.199	5.25	0.078	4.97	0.052	5.14	0.083	4.81	0.076	3.57	0.053
7.47	0.236	5.46	0.061	5.09	0.061	5.22	0.091	4.98	0.081	3.80	0.033
7.59	0.299	5.60	0.061	5.25	0.078	5.42	0.083	5.23	0.111	4.01	0.035
7.76	0.397	5.79	0.077	5.60	0.078	5.53	0.083	5.47	0.094	4.19	0.038
7.91	0.478	6.01	0.108	5.81	0.098	5.67	0.092	5.65	0.111	4.30	0.043
8.07	0.550	6.20	0.145	6.05	0.140	5.81	0.111	5.84	0.154	4.41	0.059
8.20	0.602	6.35	0.185	6.25	0.178	5.94	0.138	6.00	0.187	4.65	0.046
8.33	0.661	6.53	0.230	6.44	0.248	6.07	0.169	6.15	0.236	4.80	0.046
8.52	0.724	6.69	0.282	6.63	0.319	6.18	0.202	6.26	0.297	5.01	0.056
8.65	0.765	6.86	0.358	6.85	0.414	6.38	0.267	6.42	0.366	5.17	0.074
8.82	0.805	7.02	0.432	7.06	0.532	6.54	0.334	6.57	0.444	5.30	0.074
9.04	0.855	7.19	0.538	7.21	0.639	6.69	0.400	6.69	0.523	5.45	0.064
9.19	0.890	7.34	0.659	7.34	0.745	6.86	0.498	6.80	0.636	5.62	0.064
9.42	0.926	7.47	0.748	7.50	0.829	7.02	0.589	6.87	0.706	5.76	0.076
9.58	0.946	7.55	0.838	7.66	0.882	7.15	0.672	6.95	0.774	5.91	0.090
9.78	0.965	7.66	0.848	7.85	0.922	7.32	0.793	7.04	0.827	6.07	0.127

TABLE 9-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 12 (CONT.)	
6.18	0.152
6.26	0.180
6.42	0.233
6.52	0.276
6.66	0.332
6.88	0.432
7.03	0.514
7.18	0.605
7.32	0.713
7.46	0.804
7.55	0.846
7.66	0.887
7.82	0.918
8.00	0.944
CURVE 13 T = 594.	
1.49	0.400
1.58	0.374
1.70	0.348
1.78	0.335
1.89	0.322
1.95	0.314
2.14	0.314
2.29	0.324
2.44	0.338
2.57	0.357
2.71	0.400
2.83	0.363
2.89	0.305
3.03	0.250
3.15	0.201
3.32	0.158
3.46	0.128
3.62	0.103
3.80	0.086
4.02	0.088
4.15	0.094
4.28	0.114

λ	ε
CURVE 13 (CONT.)	
4.42	0.134
4.53	0.111
4.67	0.090
4.77	0.090
4.93	0.104
5.03	0.121
5.11	0.137
5.18	0.163
5.30	0.134
5.45	0.119
5.58	0.119
5.73	0.128
5.81	0.147
5.93	0.177
6.03	0.220
6.17	0.272
6.30	0.333
6.40	0.385
6.49	0.443
6.60	0.511
6.70	0.603
6.79	0.710
6.84	0.771
6.91	0.813
6.99	0.853
7.16	0.898
7.28	0.930
7.47	0.954
7.62	0.965
7.86	0.980
8.15	0.987
CURVE 14 T = 647.	
1.49	0.400
1.58	0.374
1.70	0.348
1.78	0.335
1.89	0.322

λ	ε
CURVE 14 (CONT.)	
2.12	0.322
2.29	0.338
2.43	0.362
2.55	0.402
2.71	0.491
2.79	0.406
2.94	0.314
3.14	0.228
3.34	0.176
3.55	0.129
3.80	0.100
4.00	0.100
4.22	0.107
4.41	0.133
4.69	0.113
4.84	0.113
5.00	0.137
5.17	0.184
5.45	0.150
5.56	0.150
5.68	0.170
5.80	0.197
5.95	0.250
6.09	0.312
6.22	0.379
6.38	0.475
6.50	0.556
6.61	0.658
6.69	0.724
6.77	0.794
6.85	0.845
6.97	0.886
7.11	0.917
7.25	0.943
7.42	0.961
7.67	0.977
8.00	0.986

λ	ε
CURVE 15 T = 865.	
1.49	0.600
1.55	0.541
1.63	0.488
1.77	0.425
1.91	0.393
2.08	0.373
2.22	0.373
2.39	0.394
2.54	0.434
2.70	0.525
2.79	0.447
2.95	0.352
3.11	0.274
3.29	0.207
3.48	0.155
3.72	0.122
3.80	0.111
4.03	0.112
4.22	0.121
4.40	0.148
4.61	0.133
4.77	0.133
4.91	0.147
5.08	0.179
5.19	0.204
5.41	0.193
5.56	0.193
5.70	0.223
5.81	0.255
5.97	0.315
6.12	0.395
6.26	0.482
6.34	0.560
6.49	0.674
6.60	0.753
6.65	0.805
6.73	0.847
6.88	0.899
7.02	0.925

λ	ε
CURVE 15 (CONT.)	
7.16	0.947
7.31	0.965
7.47	0.978
7.68	0.987
CURVE 16 T = 970.	
1.49	0.662
1.57	0.585
1.62	0.526
1.72	0.474
1.84	0.431
1.98	0.407
2.07	0.393
2.18	0.393
2.33	0.412
2.46	0.435
2.56	0.477
2.71	0.565
2.78	0.490
2.91	0.404
3.06	0.318
3.22	0.257
3.39	0.200
3.64	0.151
3.80	0.130
3.94	0.123
4.09	0.123
4.24	0.137
4.41	0.154
4.53	0.147
4.77	0.157
4.97	0.178
5.09	0.202
5.16	0.225
5.42	0.219
5.54	0.233
5.66	0.256
5.82	0.321

λ	ε
CURVE 16 (CONT.)	
5.94	0.381
6.07	0.452
6.18	0.509
6.29	0.621
6.37	0.706
6.49	0.800
6.58	0.852
6.67	0.887
6.80	0.927
6.93	0.955
7.16	0.971
7.35	0.985
7.59	1.000
8.00	0.999
CURVE 17 T = 333.	
3.00	0.091
3.25	0.074
3.54	0.061
3.80	0.052
4.01	0.054
4.61	0.046
4.82	0.050
5.07	0.050
5.32	0.043
5.58	0.043
5.78	0.054
5.94	0.065
6.07	0.065
6.23	0.105
6.36	0.141
6.50	0.175
6.54	0.180
6.66	0.186
6.81	0.176
6.97	0.176
7.12	0.191
7.22	0.215

TABLE 9-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε	λ	ε
CURVE 17 (CONT.)		CURVE 18 (CONT.)		CURVE 19 (CONT.)		CURVE 20 (CONT.)	
7.34	0.242	6.94	0.174	5.07	0.050	12.	>0.99
7.42	0.265	7.12	0.191	5.32	0.043	13.	>0.99
7.50	0.294	7.22	0.215	5.58	0.043	14.	>0.99
7.53	0.349	7.34	0.242	5.73	0.054	15.	>0.99
7.66	0.433	7.42	0.265	5.99	0.064		
7.75	0.513	7.50	0.294	6.11	0.080		
7.82	0.560	7.58	0.316	6.34	0.109		
7.90	0.596	7.66	0.362	6.51	0.146		
8.12	0.649	7.75	0.466	6.66	0.168		
8.29	0.674	7.82	0.526	6.93	0.163		
8.51	0.717	7.97	0.587	7.12	0.191		
8.77	0.761	8.15	0.630	7.22	0.215		
8.96	0.783	8.41	0.673	7.34	0.242		
9.29	0.809	8.78	0.735	7.42	0.265		
9.50	0.819	8.99	0.760	7.50	0.294		
9.94	0.835	9.32	0.783	7.67	0.351		
10.60	0.834	9.57	0.800	7.75	0.422		
10.81	0.834	9.92	0.810	7.87	0.506		
11.09	0.838	10.27	0.816	7.99	0.569		
		10.60	0.819	8.33	0.628		
CURVE 18		10.95	0.818	8.59	0.680		
T = 393.		11.38	0.827	8.91	0.720		
		11.92	0.847	9.50	0.752		
3.00	0.091	12.48	0.872	9.99	0.766		
3.25	0.074	12.84	0.886	10.60	0.776		
3.54	0.061	13.33	0.894	11.09	0.778		
3.80	0.052	13.72	0.894	11.60	0.791		
4.01	0.054	14.17	0.882	12.14	0.805		
4.51	0.046	14.82	0.862	12.78	0.813		
4.82	0.050			13.18	0.838		
5.07	0.050	CURVE 19		13.40	0.848		
5.32	0.043	T = 453.		13.70	0.849		
5.58	0.043			14.29	0.817		
5.78	0.054	3.00	0.091	15.00	0.788		
6.02	0.071	3.25	0.074				
6.14	0.089	3.54	0.061	CURVE 20			
6.29	0.110	3.80	0.052	T = 293.			
6.45	0.146	4.01	0.054				
6.57	0.171	4.61	0.046	10.	>0.99		
6.76	0.180	4.62	0.050	11.	>0.99		

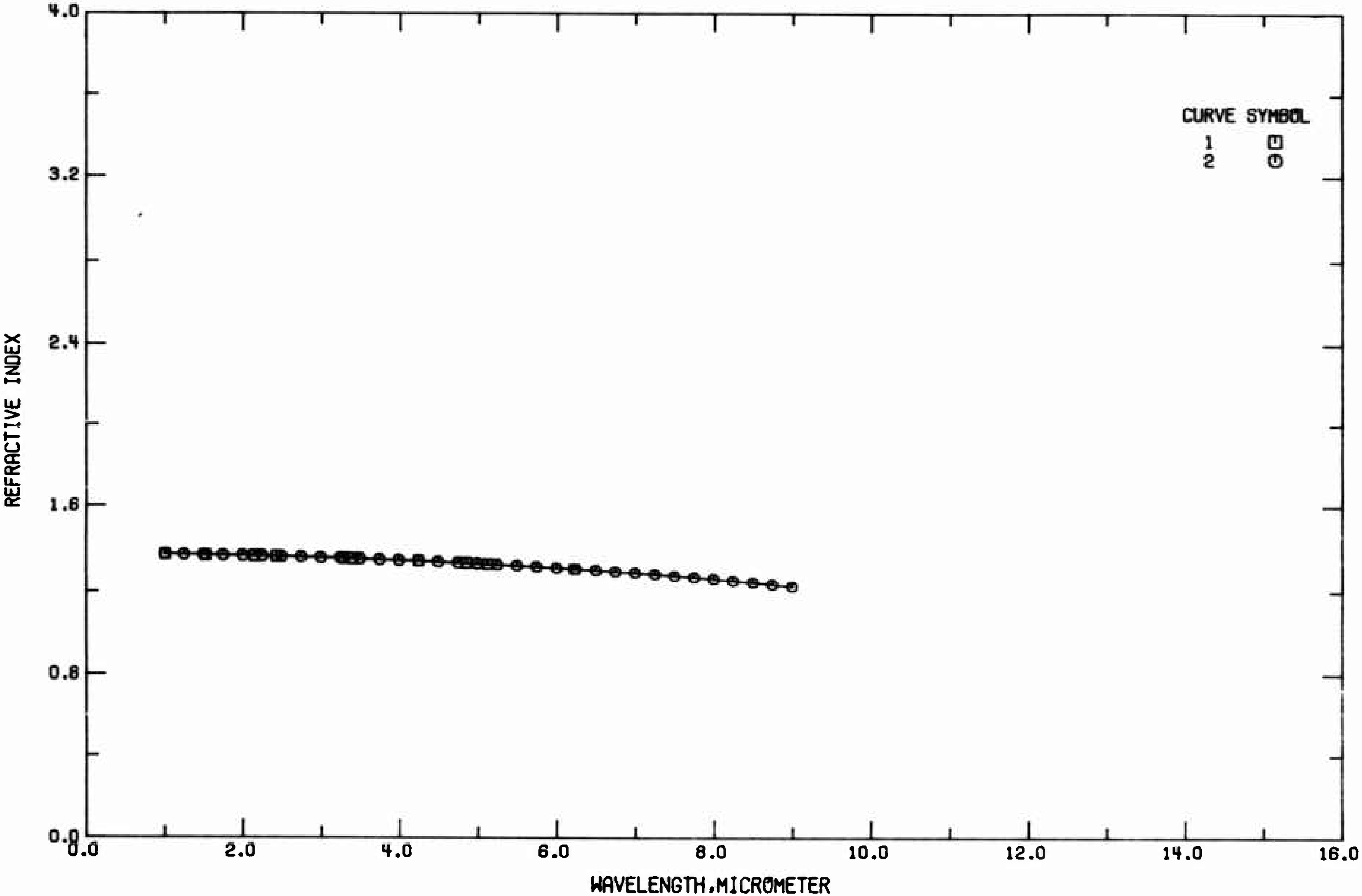


FIGURE 9-3. EXPERIMENTAL REFRACTIVE INDEX OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE).

TABLE 9-4. MEASUREMENT INFORMATION ON THE REFRACTIVE INDEX OF MAGNESIUM FLUORIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T17017	Ballard, S.S., McCarthy, K.A., and Wolfe, W.L.	1965	1.0-6.3	293	Irtran 1	Information in this reference was obtained from Eastman Kodak Co. sales literature dated 15 June 1959 and 23 February 1961; measurement temperature not explicitly given, assumed to be 293 K.
2	E62600	Eastman Kodak Co.	1971	1.0-9.0	293	Irtran 1	Measurements taken, constants in Herzberger dispersion equation determined by least squares methods; numerical values quoted here calculated from Herzberger dispersion equation: $n = n_0 + bL + cL^2 + d\lambda^2 + e\lambda^4$, where $L = 1.0/(\lambda^2 - 0.028)$, $n_0 = 1.3776955$, $b = 1.3515529 \times 10^{-3}$, $c = 2.1254394 \times 10^{-4}$, $d = -1.5041172 \times 10^{-3}$, $e = -4.4109708 \times 10^{-6}$, and λ is in micrometers, range of validity 1-[illegible] μ; measurement temperature not explicitly given, ascumed to be 293 K.

TABLE 9-5. EXPERIMENTAL REFRACTIVE INDEX OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFRACTIVE INDEX, n]

λ	n
CURVE 1 T = 293.	
1.0140	1.3776
1.5295	1.3747
2.1526	1.3708
2.4374	1.3688
3.3033	1.3639
3.4138	1.3594
4.253	1.3489
4.866	1.3402
5.136	1.3346
6.238	1.3122
CURVE 2 T = 293.	
1.0000	1.3778
1.2500	1.3763
1.5000	1.3749
1.7500	1.3735
2.0000	1.3720
2.2500	1.3702
2.5000	1.3683
2.7500	1.3663
3.0000	1.3640
3.2500	1.3614
3.5000	1.3587
3.7500	1.3558
4.0000	1.3526
4.2500	1.3492
4.5000	1.3455
4.7500	1.3416
5.0000	1.3374
5.2500	1.3329
5.5000	1.3282
5.7500	1.3232
6.0000	1.3179
6.2500	1.3122
6.5000	1.3063
6.7500	1.3000
7.0000	1.2934
CURVE 2 (CONT.)	
7.2500	1.2865
7.5000	1.2792
7.7500	1.2715
8.0000	1.2634
8.2500	1.2549
8.5000	1.2460
8.7500	1.2367
9.0000	1.2269

b. Normal Spectral Emittance (Temperature Dependence)

No experimental data was found for the temperature dependence of the normal spectral emittance of Irtran 1. However, using curves 8, 9, 10, and 11 of Tables 9-2 and 9-3, a set of provisional values for a specimen thickness of 3.8 mm and a wavelength of 3.8 μm were generated. The provisional values are listed in Table 9-6 and shown in Figure 9-4. The uncertainty is assigned a value of not more than 25%.

TABLE 9-6. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF MAGNESIUM FLUORIDE (IRTRAN 1) (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ
3.8MM THICK	
λ = 3.80	
589.	0.053
647.	0.053
865.	0.059
970.	0.071

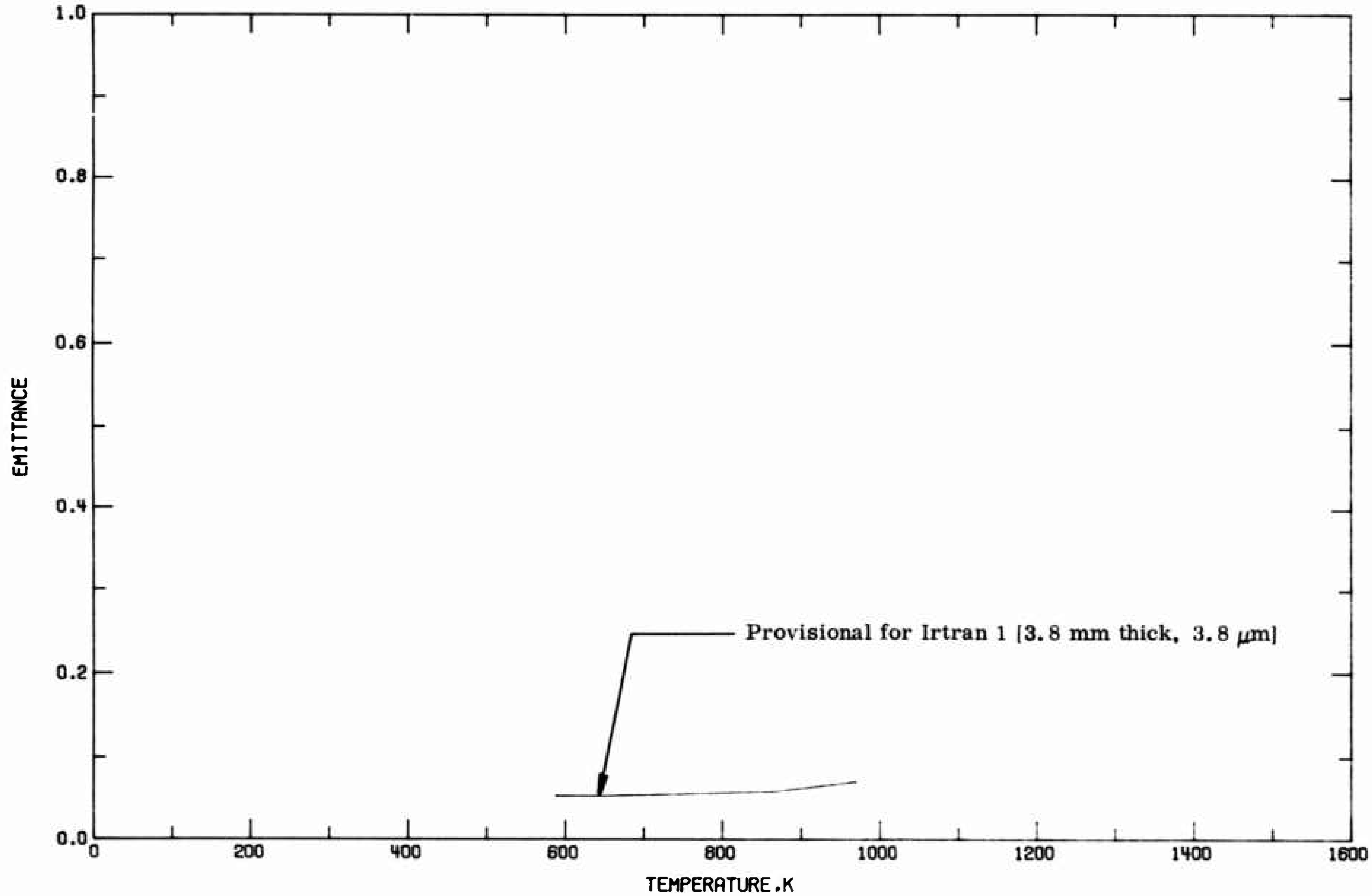


FIGURE 9-4. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF MAGNESIUM FLUORIDE (TEMPERATURE DEPENDENCE).

c. Normal Spectral Reflectance (Wavelength Dependence)

Only one set of experimental data was located for the wavelength dependence of the normal spectral reflectance of magnesium fluoride. The data is listed in Table 9-9 and shown in Figures 9-5 and 9-6. Specimen characterization and measurement information for the data are given in Table 9-8.

Calculations were carried out using the Kodak scheme, Eqs. (2.6-13) and (2.6-14), to determine the reflectance at 293 K over a range of thickness from 0.5 mm to 12 mm (curves 2-7). In addition, Hatch[T76525] presented an argument concerning the reflectance from 10 to 15 μm with the conclusion the reflectance is less than 1% (curve 8).

Values for a provisional curve at 293 K for a 2 mm thick specimen are listed in Table 9-7 and shown in Figure 9-5. These values cover a wavelength range of 3 to 6.4 μm to agree with the wavelength range for the provisional curve at 293 K for the wavelength dependence of the normal spectral emittance. The uncertainty is thought to be no more than 25%.

TABLE 9-7. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF MAGNESIUM FLUORIDE(IRTRAN 1) (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ
2MM THICK	
T = 293	
3.00	0.042
3.03	0.043
3.10	0.043
3.19	0.043
3.27	0.043
3.38	0.043
3.49	0.043
3.80	0.042
3.98	0.041
4.00	0.041
4.46	0.040
4.58	0.040
4.78	0.039
4.88	0.039
4.95	0.039
5.00	0.039
5.01	0.039
5.13	0.038
5.23	0.038
5.32	0.038
5.59	0.037
5.69	0.036
5.79	0.036
5.87	0.035
6.00	0.034
6.16	0.033
6.34	0.032
6.40	0.031

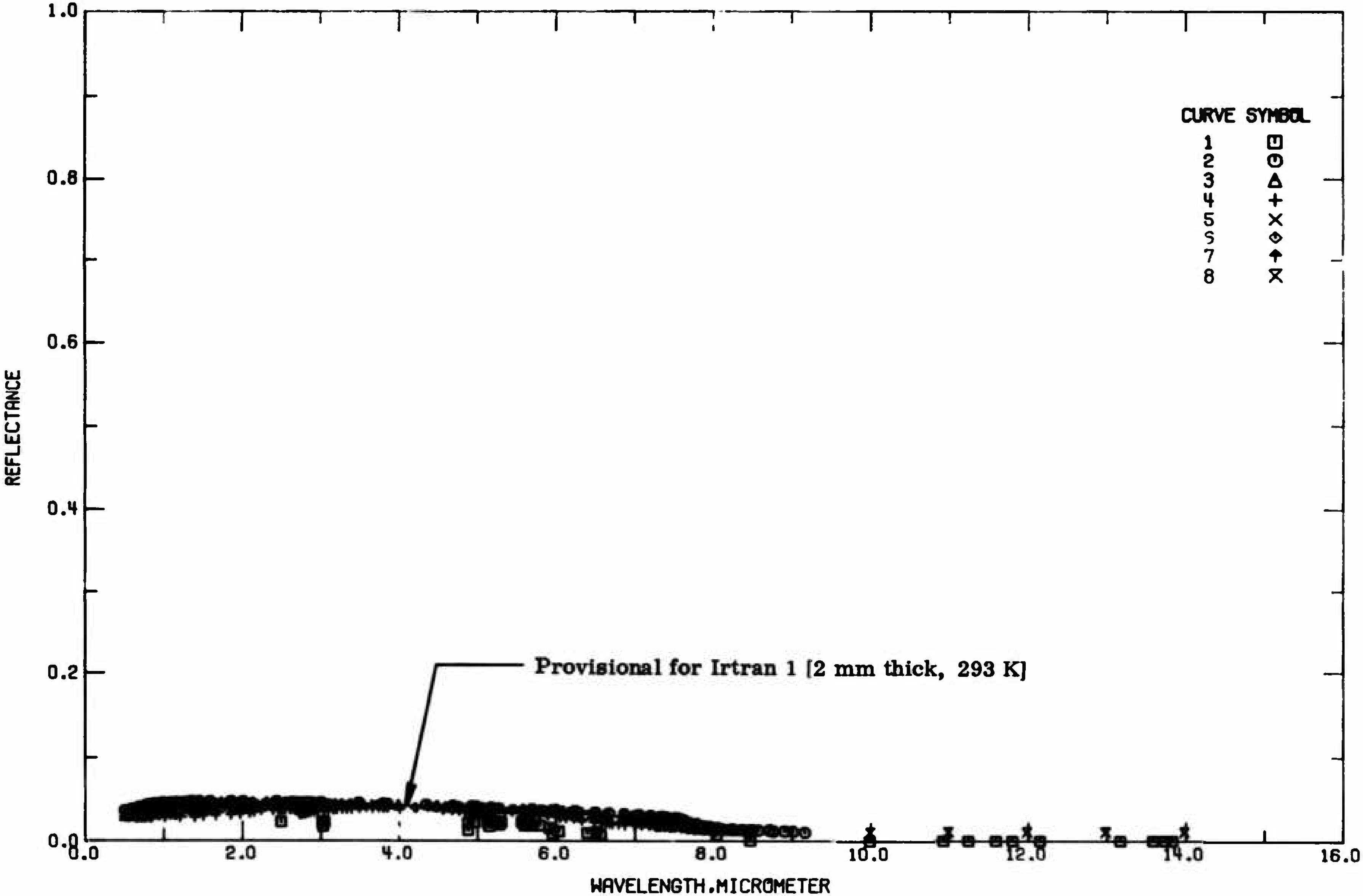


FIGURE 9-5. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE).

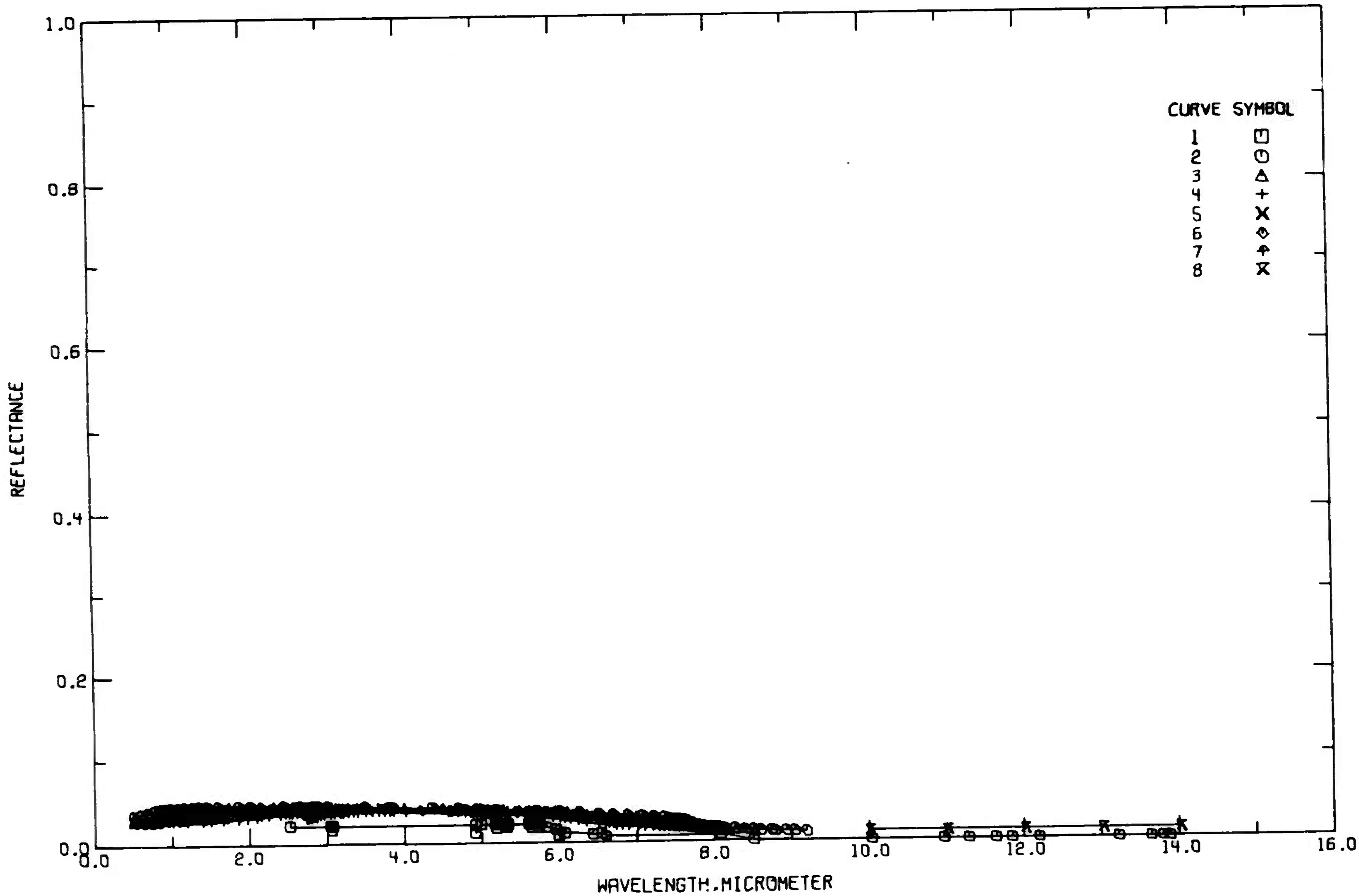


FIGURE 9-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE).

TABLE 9-8. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF MAGNESIUM FLUORIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T42761	Schaefer, J.C. and Hill, E.R.	1965	2.5-35	293	Magnesium Fluoride	Thick crystal; measurement temperature not given explicitly, assumed to be 293 K; $\theta \approx 0^\circ$, $\theta' \approx 0^\circ$.
2	E62600		1971	0.5-9.2	293	Irtran 1	Specimen thickness 0.5 mm; temperature not explicitly given, presumed to be room temperature, 293 K assigned; calculated from transmittance and refractive index; see pp. 16-18 and p. 52, [E62600].
3	E62600		1971	0.5-8.5	293	Irtran 1	Similar to the above specimen except 1 mm thick.
4	E62600		1971	0.5-8.0	293	Irtran 1	Similar to the above specimen except 2 mm thick.
5	E62600		1971	0.5-7.9	293	Irtran 1	Similar to the above specimen except 3 mm thick.
6	E62600		1971	0.65-7.7	293	Irtran 1	Similar to the above specimen except 6 mm thick.
7	E62600		1971	0.54-7.6	293	Irtran 1	Similar to the above specimen except 12 mm thick.
8	T76525	Hatch, S.E.	1962	10-15	293	Irtran 1	Thicknesses of 1 mm or greater; applicable temperature is ambient, 293 K assigned; measurements performed on a Perkin-Elmer Model 221 spectrometer with reflection attachment; reflectance less than 1 percent from 10 to 15 μ; argument presented on p. 597 of this reference that reflectance not expected to change significantly within the range of 10-15 μ up to 970 K.

TABLE 9-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ
CURVE 1	
T = 293.	
2.500	0.022
3.029	0.022
3.040	0.017
3.054	0.022
4.893	0.021
4.890	0.012
4.958	0.022
5.141	0.022
5.160	0.017
5.173	0.022
5.266	0.022
5.294	0.019
5.311	0.022
5.577	0.022
5.609	0.016
5.624	0.022
5.679	0.022
5.706	0.018
5.807	0.018
5.931	0.015
5.970	0.008
6.053	0.011
6.416	0.009
6.523	0.010
6.579	0.007
6.658	0.007
6.482	0.000
10.01	0.000
10.94	0.000
11.26	0.000
11.61	0.000
11.82	0.000
12.17	0.000
13.19	0.000
13.61	0.000
13.76	0.000
13.85	0.000
14.31	0.006
14.34	0.019

λ	ρ
CURVE 1 (CONT.)	
14.88	0.032
15.17	0.057
15.41	0.081
15.60	0.121
15.85	0.202
15.95	0.303
16.16	0.380
16.31	0.455
16.61	0.489
17.01	0.532
17.24	0.569
18.15	0.637
18.62	0.663
18.62	0.672
18.90	0.679
18.90	0.692
19.19	0.695
19.65	0.709
20.24	0.715
20.70	0.710
20.70	0.694
21.05	0.691
21.37	0.606
21.88	0.553
22.62	0.310
23.42	0.159
23.64	0.301
23.81	0.363
24.33	0.286
24.45	0.258
24.61	0.251
25.19	0.200
25.77	0.157
26.53	0.146
26.88	0.120
27.93	0.105
28.57	0.076
29.41	0.061
29.41	0.048
30.30	0.040

λ	ρ
CURVE 1 (CONT.)	
30.58	0.021
31.45	0.000
32.05	0.020
32.57	0.402
32.89	0.576
33.33	0.592
33.56	0.652
34.84	0.657
35.34	0.703
35.34	0.900
CURVE 2	
T = 293.	
0.50	0.035
0.60	0.037
0.69	0.039
0.77	0.041
0.83	0.042
0.89	0.043
0.94	0.043
0.99	0.044
1.08	0.044
1.16	0.045
1.26	0.045
1.35	0.046
1.45	0.046
1.59	0.046
1.86	0.046
2.01	0.046
2.44	0.046
2.63	0.045
2.65	0.045
2.71	0.044
2.72	0.041
2.72	0.044
2.75	0.044
2.81	0.045
2.88	0.045
3.00	0.045

λ	ρ
CURVE 2 (CONT.)	
3.49	0.044
3.80	0.043
3.85	0.043
4.35	0.042
4.69	0.041
4.93	0.040
4.99	0.040
5.18	0.039
5.70	0.037
6.00	0.036
6.25	0.035
6.50	0.033
6.68	0.032
6.87	0.031
7.06	0.030
7.21	0.029
7.34	0.023
7.41	0.027
7.50	0.026
7.54	0.026
7.59	0.025
7.63	0.024
7.70	0.021
7.78	0.019
7.83	0.018
7.86	0.017
7.89	0.016
7.95	0.016
8.01	0.015
8.06	0.015
8.12	0.014
8.25	0.014
8.38	0.013
8.49	0.013
8.58	0.012
8.72	0.012
8.77	0.011
8.91	0.011
9.02	0.011
9.17	0.010

λ	ρ
CURVE 3	
T = 293.	
0.50	0.030
0.76	0.035
0.82	0.037
0.89	0.039
0.92	0.039
1.00	0.040
1.10	0.041
1.19	0.042
1.32	0.043
1.42	0.044
1.50	0.044
1.63	0.044
1.73	0.045
2.14	0.045
2.31	0.045
2.42	0.045
2.55	0.045
2.62	0.045
2.67	0.044
2.70	0.043
2.71	0.042
2.73	0.039
2.73	0.041
2.77	0.043
2.79	0.043
2.86	0.044
2.92	0.044
3.05	0.044
3.49	0.043
3.80	0.043
3.99	0.042
4.49	0.041
4.77	0.040
5.07	0.039
5.27	0.039
5.68	0.037
5.93	0.036
6.09	0.035
6.26	0.034

λ	ρ
CURVE 3 (CONT.)	
6.50	0.032
6.98	0.029
7.10	0.028
7.20	0.027
7.28	0.026
7.35	0.025
7.43	0.025
7.47	0.024
7.53	0.023
7.56	0.022
7.63	0.020
7.70	0.018
7.74	0.017
7.78	0.017
7.81	0.016
7.84	0.015
7.87	0.015
7.90	0.015
7.92	0.014
7.94	0.014
7.98	0.014
8.03	0.014
8.05	0.014
8.11	0.014
8.17	0.013
8.26	0.013
8.35	0.013
8.51	0.012
CURVE 4	
T = 293.	
0.50	0.028
0.60	0.028
0.68	0.029
0.76	0.031
0.79	0.033
0.82	0.034
0.84	0.035
0.91	0.036

TABLE 9-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
CURVE	4(CONT.)	CURVE	4(CONT.)	CURVE	5(CONT.)	CURVE	5(CONT.)	CURVE	6(CONT.)	CURVE	6(CONT.)
0.96	0.037	5.32	0.038	0.80	0.030	5.65	0.036	1.51	0.034	5.28	0.036
1.08	0.038	5.59	0.037	0.83	0.031	5.78	0.036	1.58	0.035	5.43	0.036
1.14	0.039	5.69	0.036	0.84	0.032	5.87	0.035	1.66	0.036	5.61	0.035
1.22	0.040	5.79	0.036	0.93	0.034	6.00	0.034	1.74	0.037	5.79	0.033
1.29	0.040	5.87	0.035	0.97	0.035	6.15	0.033	1.84	0.037	5.88	0.033
1.34	0.041	6.00	0.034	1.09	0.036	6.27	0.032	1.94	0.038	5.99	0.032
1.40	0.041	6.16	0.033	1.29	0.039	6.45	0.030	2.02	0.039	6.10	0.030
1.50	0.042	6.34	0.032	1.39	0.040	6.61	0.028	2.14	0.039	6.21	0.029
1.59	0.042	6.50	0.030	1.50	0.041	6.88	0.026	2.29	0.040	6.67	0.024
1.68	0.043	6.67	0.029	1.59	0.041	7.01	0.024	2.36	0.041	7.02	0.020
1.79	0.043	6.82	0.028	1.67	0.042	7.06	0.024	2.42	0.041	7.10	0.020
1.88	0.043	6.99	0.026	1.76	0.042	7.16	0.023	2.51	0.041	7.19	0.019
2.00	0.044	7.10	0.025	2.01	0.043	7.23	0.022	2.56	0.041	7.26	0.018
2.11	0.044	7.18	0.024	2.22	0.043	7.28	0.021	2.68	0.040	7.32	0.018
2.30	0.044	7.25	0.024	2.43	0.043	7.36	0.021	2.68	0.040	7.39	0.017
2.43	0.044	7.29	0.023	2.59	0.043	7.41	0.020	2.69	0.038	7.46	0.016
2.60	0.044	7.35	0.022	2.63	0.043	7.47	0.019	2.70	0.035	7.52	0.016
2.71	0.043	7.39	0.022	2.71	0.043	7.51	0.018	2.74	0.036	7.62	0.015
2.73	0.037	7.43	0.021	2.72	0.041	7.57	0.017	2.77	0.037	7.68	0.015
2.73	0.040	7.48	0.021	2.73	0.037	7.65	0.016	2.81	0.038	7.74	0.015
2.76	0.041	7.52	0.020	2.73	0.039	7.73	0.015	2.86	0.038		
2.80	0.042	7.54	0.019	2.81	0.041	7.76	0.015	2.91	0.039	CURVE 7	
2.88	0.042	7.58	0.018	2.83	0.041	7.78	0.015	2.99	0.039	T = 293.	
2.95	0.042	7.63	0.017	2.87	0.041	7.82	0.014	3.06	0.040		
3.03	0.043	7.70	0.016	2.92	0.042	7.84	0.014	3.13	0.040	0.84	0.027
3.10	0.043	7.74	0.015	2.99	0.042	7.90	0.014	3.20	0.040	1.01	0.027
3.19	0.043	7.78	0.015	3.08	0.042			3.27	0.041	1.20	0.027
3.27	0.043	7.81	0.015	3.20	0.042	CURVE 6		3.34	0.041	1.39	0.027
3.36	0.043	7.85	0.014	3.32	0.042	T = 293.		3.44	0.041	1.50	0.028
3.49	0.043	7.89	0.014	3.49	0.042			3.54	0.041	1.66	0.029
3.80	0.042	7.92	0.014	3.70	0.042	0.65	0.027	3.71	0.041	1.85	0.030
3.98	0.041	8.02	0.014	3.80	0.042	0.71	0.027	3.80	0.040	1.97	0.031
4.46	0.040			4.43	0.040	0.76	0.027	4.21	0.039	2.09	0.032
4.63	0.040	CURVE 5		4.54	0.040	0.83	0.027	4.58	0.038	2.15	0.033
4.78	0.039	T = 293.		4.69	0.039	0.93	0.029	4.70	0.036	2.24	0.034
4.88	0.039			4.85	0.039	1.08	0.030	4.85	0.037	2.39	0.035
4.95	0.039	0.50	0.028	5.02	0.038	1.14	0.030	4.90	0.037	2.46	0.036
5.01	0.039	0.59	0.027	5.14	0.038	1.27	0.032	4.97	0.036	2.50	0.036
5.13	0.038	0.70	0.027	5.22	0.038	1.36	0.033	5.07	0.037	2.54	0.036
5.23	0.038	0.75	0.029	5.52	0.037	1.43	0.034	5.15	0.037	2.61	0.036

TABLE 9-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ
CURVE	7(CONT.)	CURVE	7(CONT.)
2.69	0.036	5.44	0.033
2.70	0.035	5.55	0.032
2.73	0.031	5.64	0.031
2.74	0.030	5.71	0.031
2.77	0.031	5.79	0.030
2.80	0.031	5.90	0.029
2.83	0.032	6.00	0.028
2.86	0.032	6.05	0.027
2.91	0.033	6.13	0.026
2.96	0.034	6.23	0.025
3.04	0.035	6.33	0.023
3.09	[illegible]	6.49	0.022
3.16	[illegible]	6.58	0.021
3.20	0.036	6.63	0.020
3.27	0.037	6.68	0.020
3.33	0.037	6.72	0.019
3.39	0.037	6.80	0.019
3.49	0.038	6.88	0.018
3.58	0.038	7.00	0.018
3.65	0.038	7.09	0.017
3.74	0.036	7.19	0.017
3.80	0.038	7.28	0.016
3.85	0.038	7.33	0.016
4.01	0.037	7.45	0.016
4.56	0.036	7.59	0.015
4.68	0.035		
4.77	0.035	CURVE 3	
4.84	0.035	T = 293.	
4.88	0.034		
4.92	0.034	10.	<0.01
4.97	0.033	11.	<0.01
5.01	0.032	12.	<0.01
5.03	0.033	13.	<0.01
5.04	0.033	14.	<0.01
5.07	0.033	15.	<0.01
5.11	0.034		
5.15	0.034		
5.19	0.034		
5.23	0.034		
5.35	0.033		

d. Angular Spectral Reflectance (Wavelength Dependence)

One set of experimental data was located for the wavelength dependence of the angular spectral reflectance of Irtran 1. Three sets are for magnesium fluoride. The data are listed in Table 9-11 and shown in Figure 9-7. Specimen characterization and measurement information for the data are given in Table 9-10.

All four sets are for room temperature measurements. The one set for Irtran 1 measured by McCarthy [T30100] is for a polished specimen 2 mm thick with the measurement taken at an angle of incidence, θ, of 30° and an angle of reflection, θ', of 30°. The data shows a decrease from about 0.04 at 4 μm to zero value at 9.5 μm. Because of the wide range in cut off exemplified by the data for the wavelength dependence of normal spectral reflectance (see the section on the wavelength dependence of the normal spectral transmittance and Figure 9-12), it was decided not to give evaluated data in this angular spectral reflectance section.

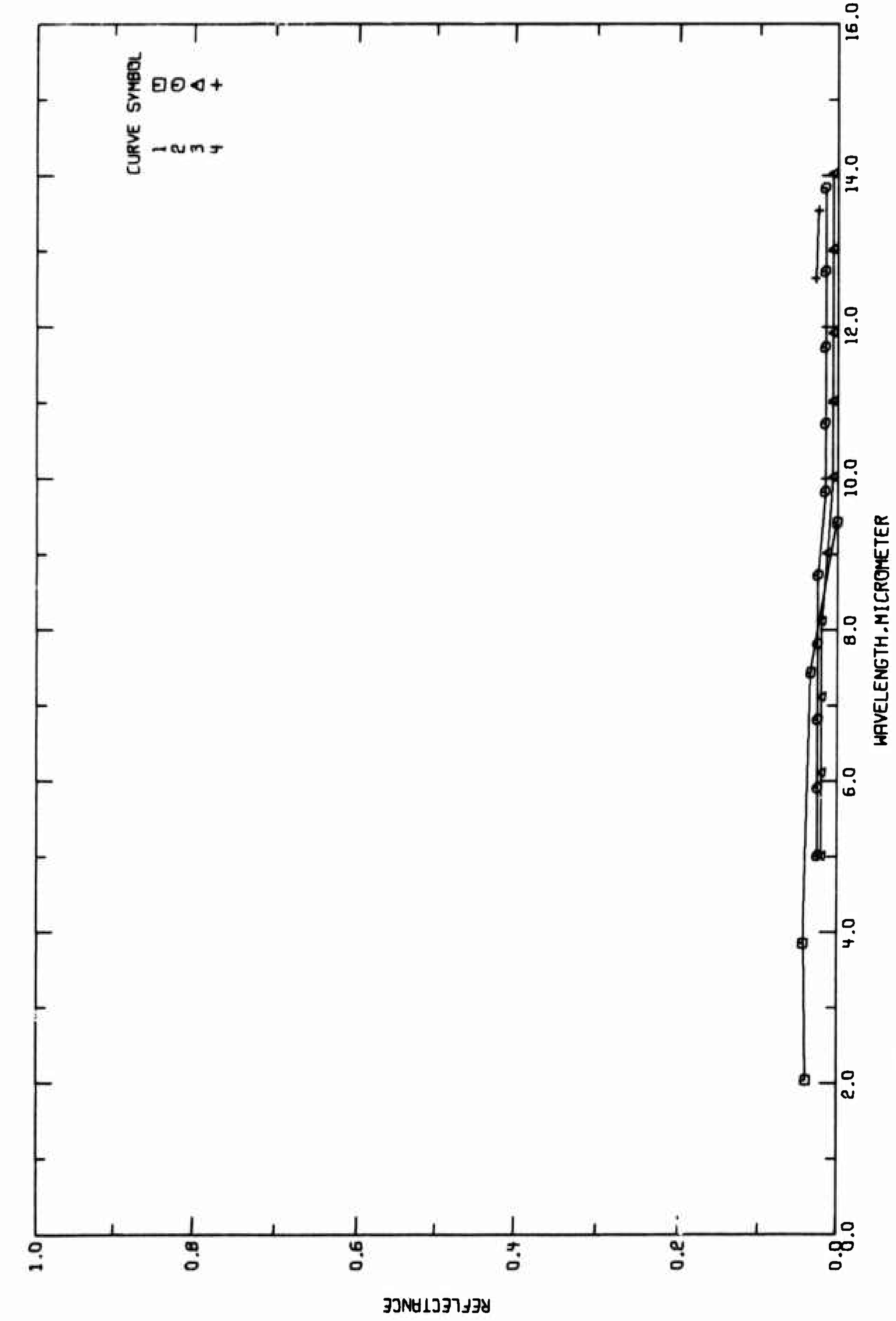


FIGURE 9-7. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE).

TABLE 9-10. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF MAGNESIUM FLUORIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T30100	McCarthy, D.E.	1963	2-50	293	Irtran 1	Specimen 2 mm thick; pressed and sintered; ground and polished to a flatness of seven fringes or better; reference standard was aluminum mirror; smooth values from figure; temperature presumed to be room temperature, 293 K assigned; $\theta = 30°$, $\theta' = 30°$.
2	T38423	Barker, A.S., Jr.	1964	5.0-130	293	MgF_2	Single crystal; cut and polished; electric vector of infrared beam perpendicular to c-axis; one sample contained 1 Ni and 1 Co and had a pink-orange color; other specimen 0.5 Ni and was optically clear; no feature of spectrum could be associated with Ni and Co doping; angle of incidence was near 15°; measurement temperature specified as room temperature, 293 K assigned; $\theta \approx 15°$, $\theta' \approx 15°$.
3	T38423	Barker, A.S., Jr.	1964	5.0-35	293	MgF_2	Similar to the above specimen except electric vector is parallel to c-axis.
4	T33043	Hunt, G.R., Perry, C.H., and Ferguson, J.	1964	13-5000	293	MgF_2	Not a single crystal; grown at Bell Telephone Laboratories; smooth values from figure; measurement temperature specified as room temperature, 293 K assigned; $\theta = 15°$, $\theta' = 15°$.

TABLE 9-11. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
CURVE 1		CURVE	2(CONT.)	CURVE	2(CONT.)	CURVE	3(CONT.)	CURVE	4(CONT.)	CURVE	4(CONT.)
T = 293.											
		8.7	0.025	34.8	0.901	16.4	0.549	15.06	0.064	31.06	0.158
2.00	0.039	9.6	0.016	37.4	0.912	16.7	0.628	15.24	0.081	31.85	0.120
3.80	0.042	10.7	0.016	39.9	0.896	16.8	0.673	15.48	0.098	32.47	0.104
7.40	0.033	11.7	0.016	40.6	0.707	17.0	0.685	15.72	0.125	33.11	0.124
9.40	0.000	12.7	0.016	40.8	0.572	17.2	0.705	15.87	0.150	33.56	0.200
14.4	0.000	13.8	0.016	45.0	0.348	17.5	0.706	16.03	0.178	34.13	0.499
15.4	0.050	14.9	0.038	50.0	0.282	17.8	0.706	16.16	0.220	34.25	0.521
16.0	0.302	15.4	0.079	55.0	0.235	18.0	0.705	16.31	0.384	34.60	0.532
17.7	0.720	15.8	0.166	59.7	0.200	18.2	0.726	16.45	0.470	35.21	0.524
19.0	0.838	16.3	0.492	64.9	0.195	18.4	0.742	16.53	0.516	35.46	0.487
20.3	0.855	16.8	0.590	69.7	0.195	18.6	0.764	16.67	0.550	35.64	0.473
21.7	0.796	17.3	0.698	74.7	0.193	19.0	0.783	16.75	0.578	36.50	0.482
22.1	0.700	18.9	0.747	80.0	0.193	20.0	0.836	16.98	0.602	37.04	0.497
23.4	0.383	20.0	0.781	85.1	0.193	20.9	0.856	17.21	0.614	37.59	0.500
24.7	0.577	20.6	0.737	89.4	0.193	21.9	0.855	17.42	0.621	38.61	0.480
25.1	0.483	21.5	0.667	94.5	0.193	23.0	0.823	17.95	0.621	39.22	0.444
25.6	0.495	21.9	0.580	99.3	0.193	23.4	0.807	18.21	0.617	40.32	0.404
27.2	0.293	22.4	0.452	97.66	0.193	23.8	0.801	18.69	0.617	42.02	0.359
29.0	0.234	23.0	0.335	95.33	0.187	24.4	0.764	19.16	0.632	44.05	0.320
30.8	0.108	23.6	0.244	90.74	0.187	25.0	0.692	19.57	0.646	46.51	0.295
32.1	0.000	23.8	0.207	87.03	0.184	25.9	0.476	20.28	0.681	51.81	0.271
32.9	0.000	24.1	0.188	83.82	0.180	37.04	0.377	20.70	0.697	56.62	0.255
33.6	0.227	24.2	0.207	80.26	0.180	25.0	0.310	21.10	0.697	67.11	0.541
34.1	0.298	24.2	0.281	76.92	0.180	28.9	0.275	21.55	0.683	81.97	0.239
35.9	0.359	24.4	0.293			30.0	0.243	21.98	0.661	95.00	0.222
37.6	0.463	24.6	0.313	CURVE 3		31.0	0.239	22.42	0.610	71.00	0.217
39.4	0.709	24.8	0.263	T = 293.		32.0	0.232	23.75	0.449	36.00	0.214
40.9	0.500	25.0	0.258			33.0	0.225	24.10	0.390	23.00	0.217
42.6	0.375	25.7	0.220	5.0	0.020	34.0	0.215	24.27	0.374	2.00	0.217
44.3	0.239	26.1	0.191	6.1	0.020	35.0	0.211	24.45	0.386		
46.7	0.171	26.6	0.168	7.1	0.020			24.51	0.450		
50.0	0.151	27.2	0.149	8.1	0.020	CURVE 4		24.75	0.462		
		28.2	0.126	9.0	0.013	T = 293.		24.83	0.449		
CURVE 2		29.2	0.039	10.0	0.006			25.25	0.388		
T = 293.		30.0	0.055	11.0	0.006	12.61	0.028	25.71	0.339		
		32.5	0.024	11.9	0.006	13.51	0.024	26.25	0.301		
5.0	0.025	33.1	0.146	13.0	0.006	14.08	0.024	26.95	0.254		
5.9	0.025	33.7	0.734	14.0	0.006	14.35	0.028	27.78	0.219		
6.8	0.025	34.2	0.630	15.0	0.028	14.58	0.037	28.82	0.190		
7.8	0.025	34.2	0.872	16.0	0.297	14.84	0.052	30.21	0.174		

e. Normal Spectral Absorptance (Wavelength Dependence)

Three sets of experimental data were located for the wavelength dependence of the normal spectral absorptance of Irtran 1. The data are listed in Table 9-14 and shown in Figures 9-8 and 9-9. Specimen characterization and measurement information for the data are given in Table 9-13.

The three sets of data were results of measurements by Stierwalt, et al. [T45698] for a 2 mm thick specimen. The measurement temperatures were 333, 393, and 453 K. The values are between 0.1 and 0.01 within the wavelength range 3 to 6 μm, rise rapidly in the range of 6.5 to 8.5 μm, and are within the range of 0.75 to 0.9 above 10 μm. This data is very similar to the normal spectral emittance data of Stierwalt, et al. [T33450] in Tables 9-2 and 9-3 and Figures 9-1 and 9-2 (curves 17, 18, and 19).

Calculations were carried out to determine the absorptance using transmittance and refractive index data. See the section on the wavelength dependence of the normal spectral emittance for more details. The results of the calculations are curves 4-9 in Table 9-14 and Figures 9-8 and 9-9.

For wavelengths greater than 7 μm, the calculations show the absorptance reaching 0.98 or greater. However, the data of Stierwalt, et al. for the lowest temperature, 333 K, does not reach 0.98. The same type of difficulty manifested itself in the data for the normal spectral emittance.

However, in a lower wavelength region, the calculations for a 2 mm thick specimen (curve 6) and the data for a 2 mm thick specimen at 333 K agree reasonably well. Therefore, between 3 and 6.4 μm, the calculated values are taken as the provisional values for 293 K with an uncertainty of 25%. The provisional values are listed in Table 9-12 and shown in Figure 9-8.

Applying Kirchhoff's law, equating normal spectral absorptance to normal spectral emittance, two more provisional curves are given (see the section on the wavelength dependence of the normal spectral emittance). One applies to a specimen thickness of 3.8 mm, a temperature of 589 K, and a wavelength range of 3 to 6.4 μm; the other applies to a thickness of 3.8 mm, a temperature of 970 K, and a wavelength range of 3 to 6.0 μm. These values are also listed in Table 9-12 and shown in Figure 9-8. Because of the low value of absorptance, the uncertainty can be as high as 25%.

TABLE 9-12. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF MAGNESIUM FLUORIDE (IRTRAN 1) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α
2MM THICK		3.8MM THICK		3.8MM THICK	
T = 293		T = 589		T = 973	
3.00	0.089	3.0	0.154	3.0	0.177
3.03	0.085	3.11	0.124	3.07	0.155
3.10	0.079	3.24	0.102	3.31	0.109
3.19	0.074	3.42	0.076	3.56	0.083
3.27	0.069	3.80	0.053	3.80	0.071
3.38	0.065	4.0	0.048	4.0	0.070
3.49	0.060	4.14	0.045	4.42	0.066
3.80	0.060	4.64	0.045	4.81	0.076
3.98	0.059	4.97	0.052	4.98	0.081
4.00	0.060	5.0	0.054	5.0	0.084
4.46	0.060	5.09	0.061	5.23	0.111
4.68	0.060	5.25	0.078	5.47	0.094
4.78	0.057	5.46	0.061	5.65	0.111
4.88	0.052	5.60	0.061	5.84	0.154
4.95	0.058	5.79	0.077	6.00	0.187
5.00	0.057	6.0	0.107		
5.01	0.058	6.01	0.108		
5.13	0.050	6.20	0.145		
5.23	0.046	6.35	0.185		
5.32	0.044	6.4	0.197		
5.59	0.045				
5.69	0.050				
5.79	0.054				
5.87	0.060				
6.00	0.071				
6.16	0.087				
6.34	0.109				
6.40	0.118				

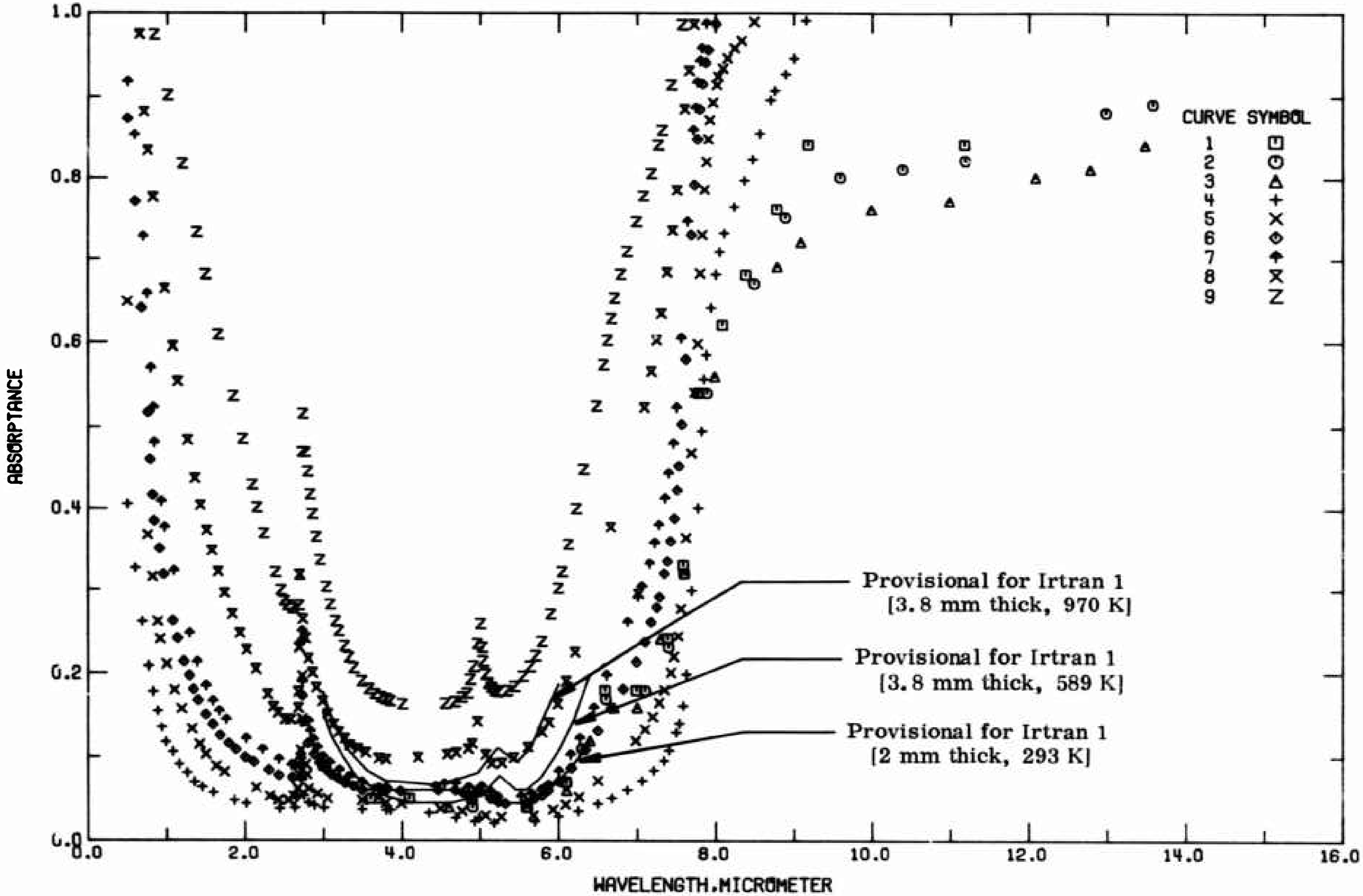


FIGURE 9-8. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE).

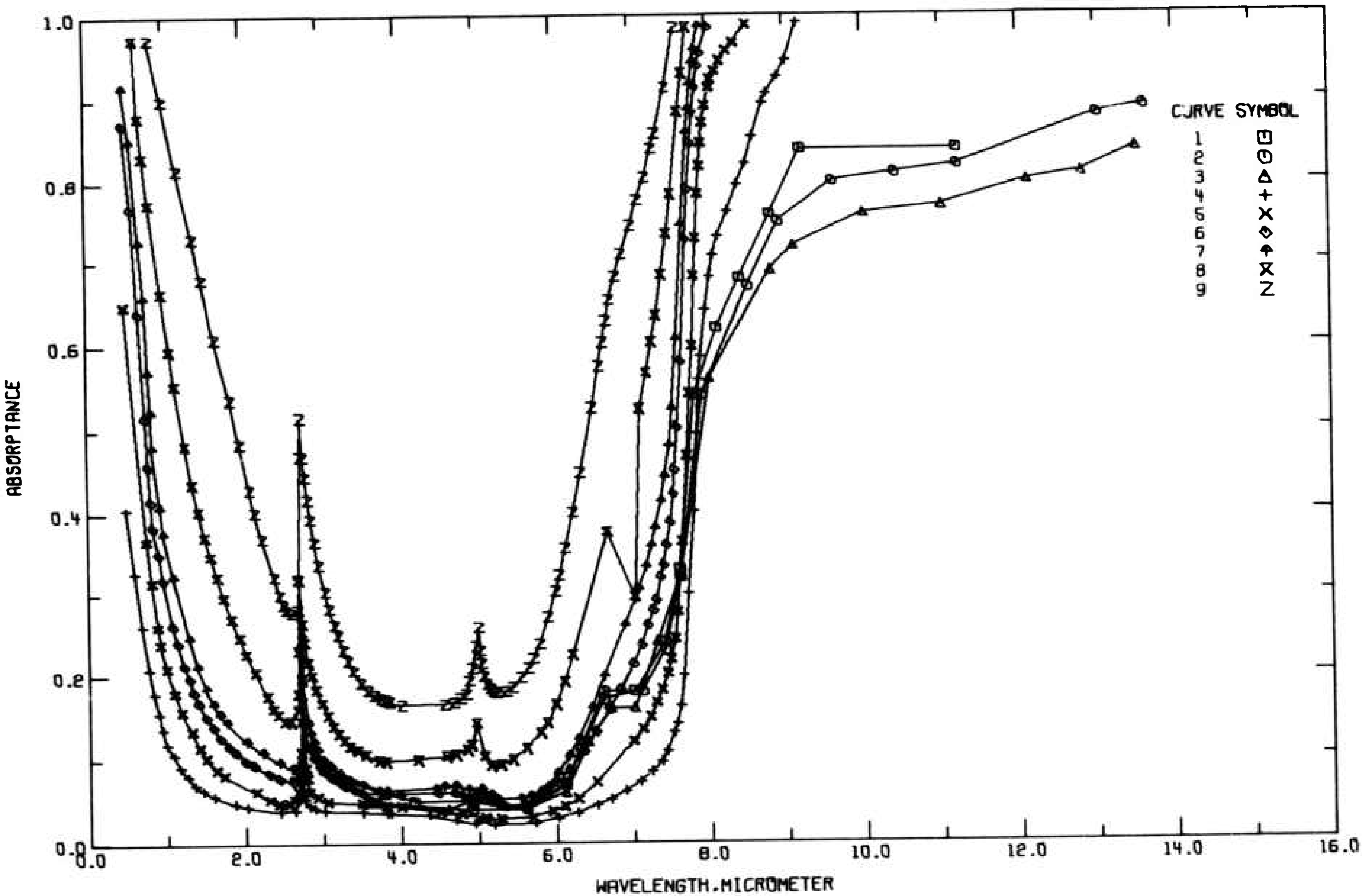


FIGURE 9-9. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE).

TABLE 9-13. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF MAGNESIUM FLUORIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T45698	Stierwalt, D.L., Bernstein, J.B., and Kirk, D.D.	1963	3.0-11	333	Irtran 1	Specimen 2 mm thick; hot pressed; measured in vacuum; smooth values from figure; $\theta = 0°$.
2	T45698	Stierwalt, D.L., et al.	1963	3-15	393	Irtran 1	Similar to the above specimen.
3	T45698	Stierwalt, D.L., et al.	1963	3-15	453	Irtran 1	Similar to the above specimen.
4	E62600		1971	0.5-9.2	293	Irtran 1	Specimen thickness 0.5 mm; temperature not explicitly given, presumed to be room temperature, 293 K assigned; calculated from transmittance and refractive index, see pp. 16-18 and p. 52, [E62600].
5	E62600		1971	0.5-8.5	293	Irtran 1	Similar to the above specimen except 1 mm thick.
6	E62600		1971	0.5-8.0	293	Irtran 1	Similar to the above specimen except 2 mm thick.
7	E62600		1971	0.5-7.9	293	Irtran 1	Similar to the above specimen except 3 mm thick.
8	E62600		1971	0.65-7.7	293	Irtran 1	Similar to the above specimen except 6 mm thick.
9	E62600		1971	0.84-7.6	293	Irtran 1	Similar to the above specimen except 12 mm thick.

TABLE 9-14. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α
CURVE 1	
T = 333.	
3.00	0.09
3.70	0.06
4.10	0.05
4.90	0.05
5.60	0.04
5.10	0.07
6.60	0.18
7.00	0.18
7.40	0.24
7.60	0.33
7.80	0.54
8.10	0.62
8.40	0.68
8.80	0.76
9.20	0.84
11.2	0.84
CURVE 2	
T = 393.	
3.00	0.09
3.60	0.05
4.90	0.04
5.60	0.04
6.10	0.07
6.30	0.11
6.60	0.17
7.10	0.18
7.40	0.23
7.60	0.32
7.90	0.54
8.50	0.67
8.90	0.75
9.60	0.80
10.4	0.81
11.2	0.82
13.0	0.88
13.6	0.89
14.8	0.85
CURVE 3	
T = 453.	
3.00	0.09
3.70	0.05
4.60	0.04
4.90	0.05
5.60	0.04
6.10	0.06
6.40	0.12
6.70	0.16
7.00	0.16
7.30	0.24
7.60	0.32
8.00	0.56
8.30	0.69
9.10	0.72
10.0	0.76
11.0	0.77
12.1	0.80
12.8	0.81
13.5	0.84
15.0	0.78
CURVE 4	
T = 293.	
0.50	0.405
0.60	0.326
0.69	0.260
0.77	0.208
0.83	0.178
0.89	0.155
0.94	0.136
0.99	0.118
1.08	0.105
1.16	0.091
1.26	0.081
1.35	0.070
1.45	0.064
1.59	0.057
1.86	0.048
CURVE 4(CONT.)	
2.01	0.044
2.44	0.033
2.63	0.039
2.65	0.051
2.71	0.076
2.72	0.142
2.72	0.073
2.75	0.054
2.81	0.045
2.88	0.042
3.00	0.039
3.49	0.037
3.80	0.036
3.99	0.036
4.35	0.033
4.69	0.027
4.93	0.023
4.99	0.027
5.18	0.021
5.70	0.023
6.00	0.029
6.25	0.035
6.50	0.044
6.68	0.051
6.87	0.061
7.06	0.072
7.21	0.084
7.34	0.096
7.41	0.108
7.50	0.130
7.54	0.141
7.59	0.162
7.63	0.199
7.70	0.299
7.78	0.401
7.83	0.495
7.86	0.557
7.89	0.585
7.95	0.641
8.01	0.681
CURVE 4(CONT.)	
8.06	0.708
8.12	0.731
8.25	0.763
8.33	0.796
8.49	0.822
8.56	0.854
8.72	0.895
8.77	0.906
8.91	0.926
9.02	0.945
9.17	0.990
CURVE 5	
T = 293.	
0.50	0.648
0.76	0.367
0.82	0.315
0.89	0.260
0.92	0.239
1.00	0.210
1.10	0.180
1.19	0.158
1.32	0.134
1.42	0.115
1.50	0.103
1.63	0.089
1.73	0.082
2.14	0.063
2.31	0.053
2.42	0.048
2.55	0.048
2.62	0.053
2.67	0.062
2.70	0.078
2.71	0.108
2.73	0.197
2.73	0.146
2.77	0.091
2.79	0.079
CURVE 5(CONT.)	
2.81	0.062
2.92	0.056
3.05	0.050
3.49	0.046
3.80	0.045
3.99	0.044
4.49	0.038
4.77	0.035
5.07	0.030
5.27	0.028
5.68	0.030
5.93	0.037
6.09	0.043
6.26	0.052
6.50	0.072
6.98	0.120
7.10	0.134
7.20	0.149
7.28	0.166
7.35	0.181
7.43	0.201
7.47	0.219
7.53	0.243
7.56	0.276
7.63	0.364
7.70	0.468
7.74	0.541
7.76	0.598
7.81	0.682
7.84	0.729
7.87	0.785
7.90	0.819
7.92	0.847
7.94	0.871
7.98	0.892
8.03	0.913
8.05	0.923
8.11	0.933
8.17	0.945
8.26	0.957
CURVE 5(CONT.)	
8.35	0.966
8.51	0.988
CURVE 6	
T = 293.	
0.50	0.872
0.60	0.769
0.68	0.640
0.76	0.516
0.79	0.459
0.82	0.416
0.84	0.384
0.91	0.350
0.96	0.313
1.08	0.251
1.14	0.240
1.22	0.213
1.29	0.197
1.34	0.181
1.40	0.168
1.50	0.151
1.59	0.139
1.68	0.126
1.79	0.116
1.88	0.109
2.00	0.099
2.11	0.094
2.30	0.084
2.43	0.073
2.60	0.075
2.71	0.089
2.73	0.237
2.73	0.174
2.76	0.143
2.80	0.116
2.85	0.103
2.95	0.093
3.03	0.085
3.10	0.079

TABLE 9-14. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α	λ	α	λ	α	λ	α
CURVE	5(CONT.)	CURVE	6(CONT.)	CURVE	7(CONT.)	CURVE	8	CURVE	8(CONT.)	CURVE	9(CONT.)
3.19	0.074	7.78	0.847	3.08	0.093	T = 293.		3.54	0.105	1.66	0.608
3.27	0.069	7.81	0.884	3.20	0.084	0.65	0.973	3.71	0.098	1.85	0.536
3.36	0.065	7.65	0.914	3.32	0.076	0.71	0.880	3.80	0.097	1.97	0.465
3.49	0.060	7.89	0.940	3.49	0.070	0.76	0.832	4.21	0.099	2.09	0.429
3.60	0.060	7.92	0.955	3.70	0.063	0.83	0.774	4.58	0.103	2.15	0.401
3.96	0.059	8.02	0.986	3.80	0.063	0.98	0.663	4.70	0.105	2.24	0.369
4.46	0.060			4.43	0.065	1.08	0.594	4.85	0.110	2.39	0.321
4.68	0.060	CURVE 7		4.54	0.068	1.14	0.553	4.90	0.116	2.46	0.299
4.78	0.057	T = 293.		4.69	0.069	1.27	0.483	4.97	0.143	2.50	0.286
4.88	0.052			4.85	0.064	1.36	0.436	5.07	0.103	2.54	0.280
4.95	0.058	0.50	0.916	5.02	0.065	1.43	0.403	5.15	0.092	2.61	0.276
5.01	0.058	0.59	0.851	5.14	0.058	1.51	0.372	5.28	0.093	2.69	0.280
5.13	0.050	0.70	0.726	5.22	0.052	1.58	0.347	5.43	0.099	2.70	0.318
5.23	0.046	0.75	0.657	5.52	0.053	1.66	0.321	5.61	0.112	2.73	0.469
5.32	0.044	0.80	0.569	5.65	0.056	1.74	0.295	5.79	0.130	2.74	0.515
5.59	0.045	0.83	0.522	5.78	0.061	1.84	0.269	5.88	0.142	2.77	0.469
5.69	0.050	0.84	0.480	5.87	0.067	1.94	0.246	5.99	0.164	2.80	0.445
5.79	0.054	0.93	0.458	6.00	0.083	2.02	0.226	6.10	0.191	2.83	0.417
5.87	0.060	0.97	0.376	6.15	0.103	2.14	0.204	6.21	0.224	2.86	0.393
6.00	0.071	1.09	0.322	6.27	0.123	2.29	0.175	6.57	0.377	2.91	0.365
6.16	0.087	1.29	0.246	6.45	0.160	2.36	0.160	7.02	0.295	2.96	0.336
6.34	0.109	1.39	0.212	6.61	0.198	2.42	0.153	7.10	0.523	3.04	0.303
6.50	0.132	1.50	0.185	6.88	0.260	2.51	0.145	7.19	0.566	3.09	0.281
6.67	0.159	1.59	0.167	7.01	0.291	2.58	0.145	7.26	0.602	3.16	0.261
6.82	0.182	1.67	0.155	7.06	0.304	2.68	0.159	7.32	0.634	3.20	0.249
6.39	0.213	1.76	0.145	7.16	0.332	2.68	0.178	7.39	0.683	3.27	0.231
7.10	0.236	2.01	0.122	7.23	0.358	2.69	0.229	7.46	0.734	3.33	0.218
7.18	0.260	2.22	0.109	7.28	0.380	2.70	0.318	7.52	0.784	3.39	0.206
7.25	0.278	2.43	0.097	7.36	0.413	2.74	0.263	7.62	0.884	3.49	0.191
7.29	0.291	2.59	0.090	7.41	0.443	2.77	0.240	7.68	0.935	3.58	0.182
7.35	0.320	2.63	0.090	7.47	0.480	2.81	0.216	7.74	0.985	3.66	0.176
7.39	0.335	2.71	0.098	7.51	0.523	2.86	0.200			3.74	0.172
7.43	0.360	2.72	0.142	7.57	0.605	2.91	0.183	CURVE 9		3.80	0.170
7.48	0.389	2.73	0.249	7.65	0.745	2.99	0.167	T = 293.		3.85	0.168
7.52	0.423	2.73	0.190	7.73	0.858	3.06	0.152			4.01	0.164
7.54	0.452	2.81	0.143	7.76	0.886	3.13	0.139	0.64	0.973	4.56	0.165
7.56	0.503	2.83	0.131	7.78	0.916	3.20	0.130	1.01	0.900	4.68	0.167
7.63	0.580	2.87	0.121	7.82	0.942	3.27	0.122	1.20	0.816	4.77	0.172
7.70	0.729	2.92	0.111	7.84	0.957	3.34	0.114	1.39	0.731	4.84	0.177
7.74	0.791	2.99	0.100	7.90	0.986	3.44	0.110	1.50	0.680	4.88	0.193

TABLE 9-14. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α)

λ	α
CURVE	9(CONT.)
4.92	0.236
4.97	0.234
5.01	0.258
5.03	0.230
5.04	0.214
5.07	0.199
5.11	0.189
5.15	0.184
5.19	0.190
5.23	0.179
5.35	0.180
5.44	0.135
5.55	0.197
5.64	0.205
5.71	0.220
5.79	0.237
5.98	0.270
6.00	0.302
6.05	0.322
6.13	0.356
6.23	0.400
6.33	0.448
6.49	0.525
6.56	0.574
6.63	0.602
6.68	0.628
6.72	0.653
6.80	0.681
6.88	0.709
7.00	0.745
7.09	0.777
7.19	0.805
7.28	0.849
7.33	0.858
7.45	0.913
7.59	0.985

f. Normal Spectral Absorptance (Temperature Dependence)

No experimental data was found for the temperature dependence of the normal spectral absorptance of Irtran 1. However, using curves 8, 9, 10, and 11 of Tables 9-2 and 9-3 together with Kirchhoff's law, Eq. (2.3-7), a set of provisional values for a specimen thickness of 3.8 mm and at a wavelength of 3.8 μm was generated. The provisional values are listed in Table 9-15 and shown in Figure 9-10. The uncertainty is assigned a value of not more than 25%.

TABLE 9-15. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF MAGNESIUM FLUORIDE (IRTRAN 1) (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

T	α
3.8MM THICK	
λ = 3.80	
589.	0.053
647.	0.053
865.	0.059
970.	0.071

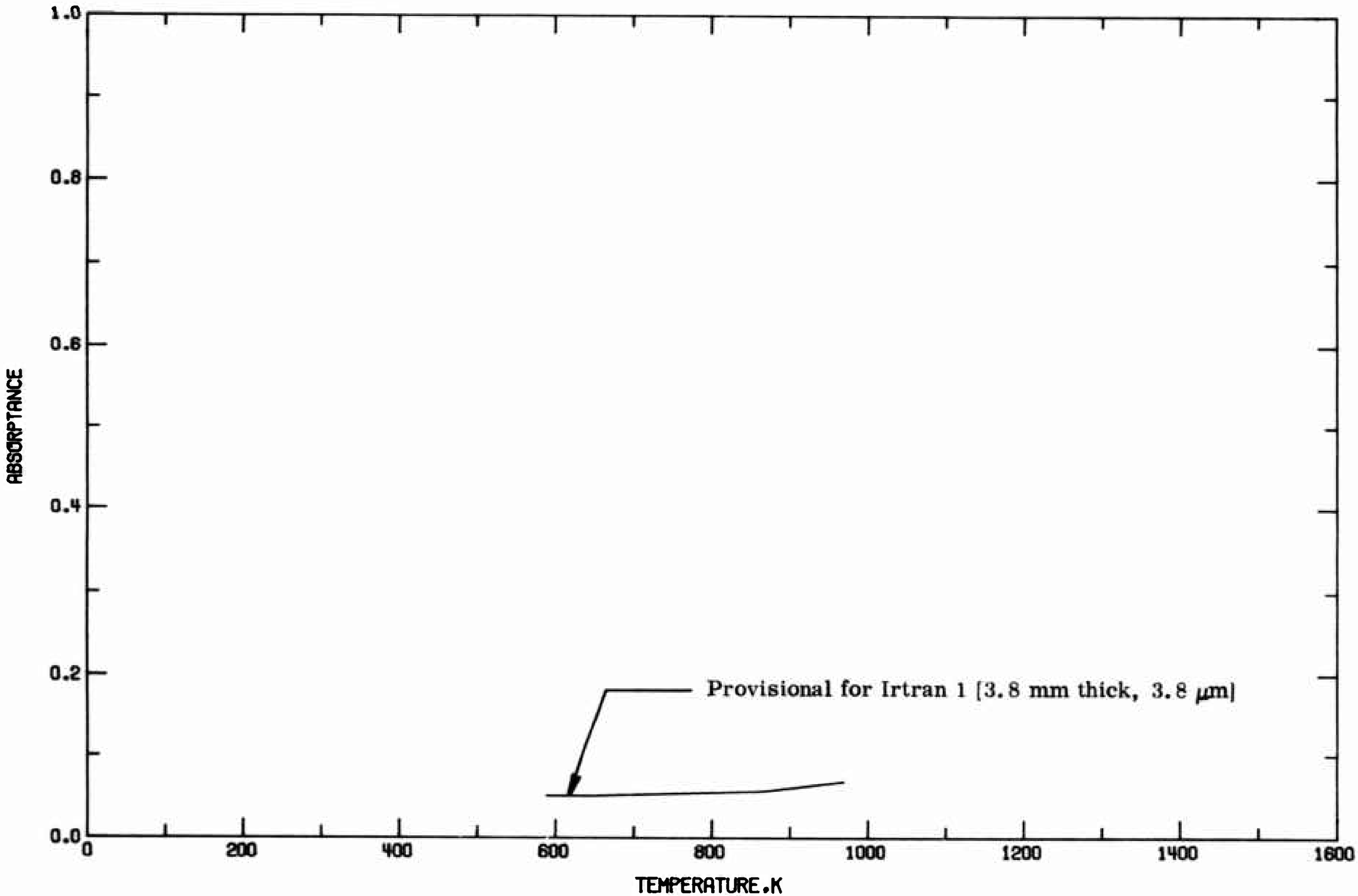


FIGURE 9-10. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF MAGNESIUM FLUORIDE (TEMPERATURE DEPENDENCE).

g. Normal Spectral Transmittance (Wavelength Dependence)

A total of 30 sets of experimental data were found for the wavelength dependence of the normal spectral transmittance of magnesium fluoride. The data are listed in Table 9-18 and shown in Figures 9-11 and 9-12. Specimen characterization and measurement information for the data are given in Table 9-17.

The data reported by Linsteadt [T38121] (curves 8 and 9) was supposedly for a 1.02 mm thick specimen of Irtran 1. However, the shape is so different from curves 15, 21, and 26, all of which apply to an approximately 1 mm thick specimen at room temperature, that the conclusion is reached that the material is not Irtran 1 contrary to what was reported for curves 8 and 9.

A look at curves 15 and 21 shows there is considerable difference in the high wavelength cut-off region. The data of curve 15 applies to a specimen thickness of 1.02 mm at a temperature of 300 K; the data in curve 21 applies to a specimen thickness of 1 mm at 293 K. Above 8 μm, curve 15 is considerably above curve 21. In addition, curve 15 reaches zero transmittance at 9.93 μm while for curve 21 it is 8.51 μm.

A comparison between curve 22, a specimen thickness of 2 mm, a measurement temperature of 293 K, and curve 1, a specimen thickness of 2 mm and a measurement temperature of 293 K shows differences. For most of the wavelength region from 7 to 10 μm, curve 1 is considerably above curve 22. For example, at 8 μm curve 22 is near zero while curve 1 is 0.432. The absorption band in the range 2.7-2.8 μm also shows differences between the two curves. Curve 1 at 2.80 μm is 0.607 while curve 22 is 0.842.

Because of these differences, a provisional curve at 293 K for a specimen thickness of 2 mm is only given for the wavelength range 3 to 7 μm. The uncertainty at 7 μm is 12% and, therefore, this uncertainty is assigned to this curve. These provisional values are based on curve 22 and the values are listed in Table 9-16 and shown in Figure 9-11.

Transmittance data was given by Ballard, et al. [T17017] for a 1.75 mm thick specimen at several high temperatures: curve 17 at 673 K, curve 18 at 873 K, and curve 19 at 1073 K. Curve 16 is at 299 K for the same thickness. The curves are identical up to 5.4 μm but above that wavelength the effect of increasing temperature is to decrease the transmittance and also to decrease the wavelength at which the transmittance reaches zero. Since the shape of curve 16, for 299 K and 1.75 mm thick, is different enough from curve 22 for 293 K and 2 mm thick, it is not thought justified to give evaluated data over a range of wavelengths for the highest temperature, i.e., 1073 K.

However, one fact that will be used in the next section is pertinent to make here. From curves 16 through 19, it is noted the transmittance has the same value for 299, 673, 873, and 1033 K at a wavelength of 3.8 μm.

TABLE 9-16. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (IRTRAN 1) (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ
2MM THICK	
T = 293	
3.00	0.869
3.03	0.872
3.10	0.873
3.19	0.883
3.27	0.888
3.38	0.892
3.49	0.897
3.80	0.898
3.98	0.899
4.00	0.899
4.46	0.900
4.68	0.900
4.78	0.904
4.88	0.909
4.95	0.903
5.00	0.904
5.01	0.903
5.13	0.912
5.23	0.916
5.32	0.918
5.59	0.918
5.69	0.914
5.79	0.910
5.87	0.905
6.00	0.895
6.16	0.880
6.34	0.859
6.40	0.851
6.50	0.838
6.67	0.812
6.82	0.790
6.99	0.761
7.00	0.756

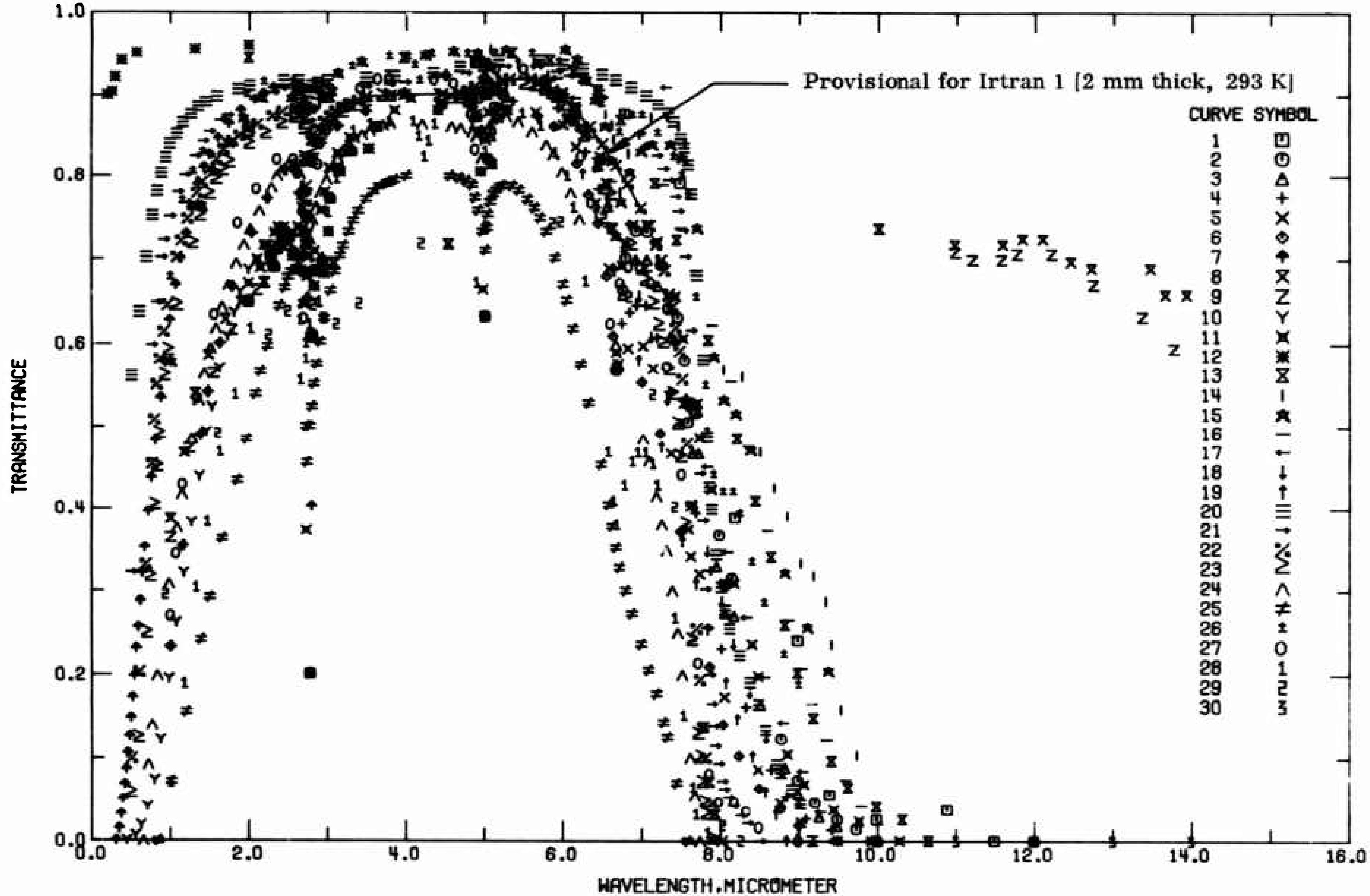


FIGURE 9-11. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE).

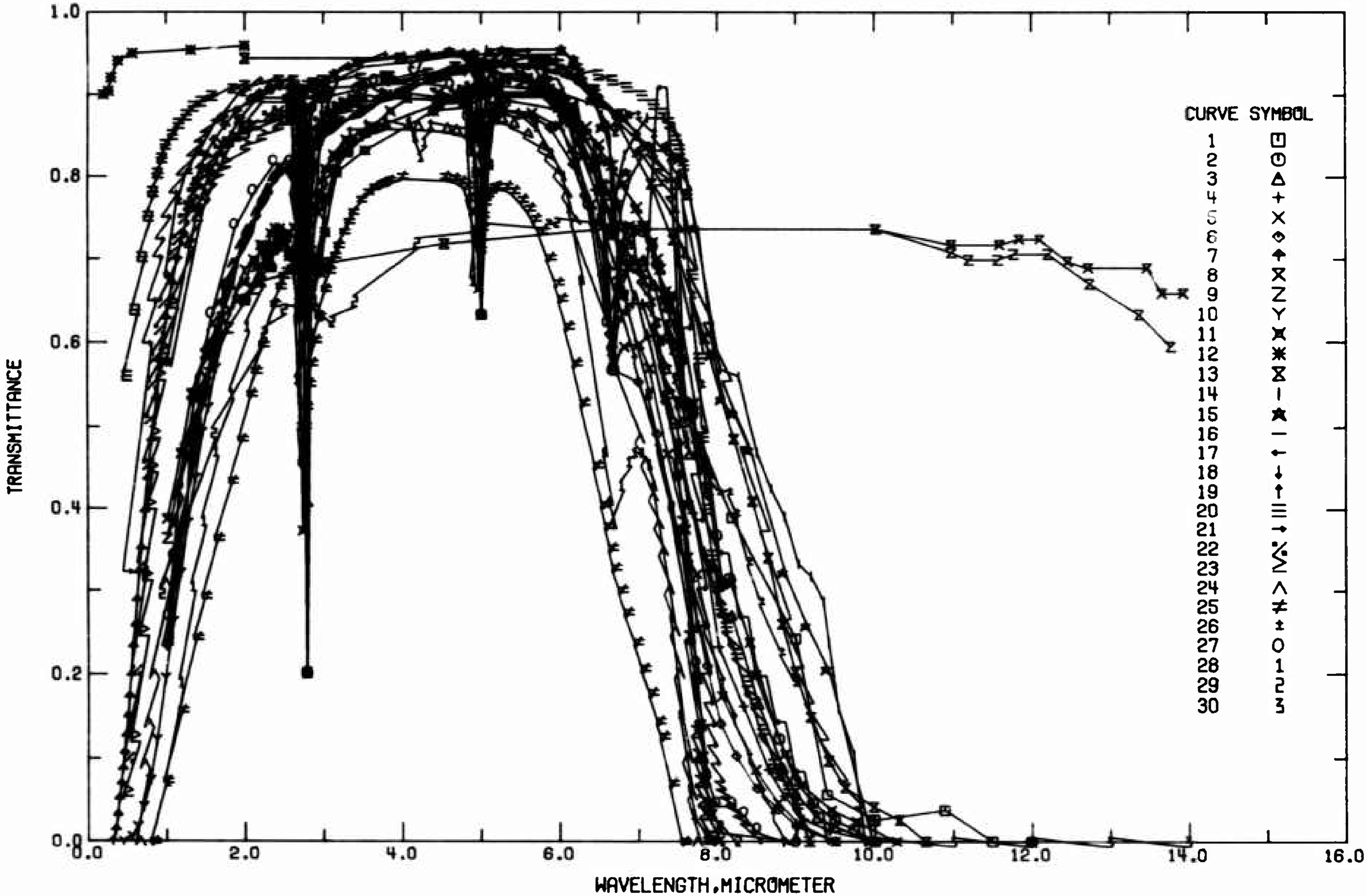


FIGURE 9-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE).

TABLE 9-17. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T30100	McCarthy, D.E.	1963	2-50	293	Irtran 1	Specimen 2 mm thick; pressed and sintered; ground and polished to a flatness of seven fringes or better; reference standard was aluminum mirror; smooth values from figure; temperature presumed to be room temperature, 293 K assigned; Beckman IR-5A used in 2-16 μ range and Beckman IR-7 with CsI interchange used in 12.5-50 μ range; $\theta = 0^\circ$, $\theta' = 0^\circ$.
2	T38674 T20810	Gillespie, D.T., Olsen, A.L., and Nichols, L.W.	1965	2-12	298	Irtran 1	Specimen 3.150 cm in diameter and 2.60 mm thick; hot-pressed; optically polished flat to within 5 green mercury fringes and a parallelism tolerance of ±2.5 μ; smooth values from figure; Perkin-Elmer Model 21 spectrophotometer with sodium chloride optics used; $\theta = 0^\circ$, $\theta' = 0^\circ$.
3	T38674 T20810	Gillespie, D.T., et al.	1965	2-12	373	Irtran 1	The above specimen.
4	T38674 T20810	Gillespie, D.T., et al.	1965	2-12	473	Irtran 1	The above specimen.
5	T38674 T20810	Gillespie, D.T., et al.	1965	2-12	573	Irtran 1	The above specimen.
6	T38674 T20810	Gillespie, D.T., et al.	1965	2-12	673	Irtran 1	The above specimen.
7	T44164	McCarthy, D.E.	1967	0.31-3.1	293	Irtran 1	Specimen 2.0 mm thick; specimen flat to within ten fringes or better of mercury green line, surfaces were parallel to within 0.001 mm/mm of length; pressed and sintered; measurements made on commercial double-beam instruments; reported error ±2%.
8	T38121	Linsteadt, G.	1964	1.0-15	50	Irtran 1	Specimen 1.27 cm in diameter and 1.02 mm thick; measurements made on Perkin-Elmer Model 221 spectrophotometer with NaCl optics; $\theta = 0^\circ$, $\theta' = 0^\circ$.
9	T38121	Linsteadt, G.	1964	1.0-15	300	Irtran 1	The above specimen.
10	T36646	Olsen, A.L. and McBride, W.R.	1963	0.44-2.0	293	Irtran 1	Polycrystalline compact; cut, ground, and polished to provide plane parallel samples of thickness 0.110 in. (2.70 mm), values of thickness given in paper; comparative Knoop hardness number under 100 g load was 625; measurements performed with Cary 14 spectrometer; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 0^\circ$, $\theta' = 0^\circ$.
11	T36646	Olsen, A.L. and McBride, W.R.	1963	2.0-10	293	Irtran 1	The above specimen except measurement performed with a Perkin-Elmer 221 spectrometer.
12	T36646	Olsen, A.L. and McBride, W.R.	1963	0.20-2.0	293	Magnesium fluoride	99.95 pure (estimate) prior to growth; single crystal; cut, ground, and polished to provide plane parallel samples of thickness 0.110 in. (2.70 mm), values of thickness given in paper; grown by Stockbarger method and obtained from Semi-Elements, Inc., Saxonburg, Pennsylvania; comparative Knoop hardness number under 100 g load was 415; measurements performed with Cary 14 spectrometer; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 0^\circ$, $\theta' = 0^\circ$.
13	T36646	Olsen, A.L. and McBride, W.R.	1963	2.0-11	293	Magnesium fluoride	The above specimen except measurement performed with a Perkin-Elmer 221 spectrometer.
14	T35848	Linsteadt, G.	1965	1.0-9.9	50	Irtran 1	Specimen 1.27 cm in diameter and 1.02 mm thick; measurements made on Perkin-Elmer Model 221 spectrophotometer with NaCl optics; $\theta = 0^\circ$, $\theta' = 0^\circ$.
15	T35848	Linsteadt, G.	1965	1.0-9.9	300	Irtran 1	The above specimen.

TABLE 9-17. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
16	T17017	Ballard, S.S., McCarthy, K.A., and Wolfe, W.L.	1961	1.0-10.0	299	Irtran 1	Specimen 1.75 mm thick; specular transmittance; information in this reference was obtained from Eastman Kodak Co. sales literature dated 15 June 1959 and 23 February 1961.
17	T17017	Ballard, S.S., et al.	1961	1.0-9.5	673	Irtran 1	Similar to the above specimen.
18	T17017	Ballard, S.S., et al.	1961	1.0-9.2	873	Irtran 1	Similar to the above specimen.
19	T17017	Ballard, S.S., et al.	1961	1.0-8.8	1073	Irtran 1	Similar to the above specimen.
20	E62600	Eastman Kodak Co.	1971	0.50-9.2	293	Irtran 1	Specimen thickness 0.5 mm; uncoated; spectral transmittance; temperature not explicitly mentioned, presumed to be room temperature, 293 K assigned; smooth values from figure.
21	E62600	Eastman Kodak Co.	1971	0.5-8.5	293	Irtran 1	Similar to the above specimen except thickness 1 mm.
22	E62600	Eastman Kodak Co.	1971	0.5-8.0	293	Irtran 1	Similar to the above specimen except thickness 2 mm.
23	E62600	Eastman Kodak Co.	1971	0.5-7.9	293	Irtran 1	Similar to the above specimen except thickness 3 mm.
24	E62600	Eastman Kodak Co.	1971	0.65-7.7	293	Irtran 1	Similar to the above specimen except thickness 6 mm.
25	E62600	Eastman Kodak Co.	1971	0.84-7.6	293	Irtran 1	Similar to the above specimen except thickness 12 mm.
26	T76525	Hatch, S.E.	1962	1.0-9.0	293	Irtran 1	Specimen thickness 1 mm; smooth values from figure; called "ambient transmittance", presumed room temperature, 293 K assigned; $\theta = 0^\circ$, $\theta' = 0^\circ$.
27	T76525	Hatch, S.E.	1962	1.0-9.0	293	Irtran 1	Similar to the above specimen except thickness 3.8 mm.
28	T76525	Hatch, S.E.	1962	1.0-9.0	293	Irtran 1	Similar to the above specimen except thickness 7.6 mm.
29	T53988	Ballard, S.S.	1965	0.93-8.3	293	Irtran 1	Specimen 6.2 mm thick; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K.
30	T76525	Hatch, S.E.	1962	10-15	293	Irtran 1	Thicknesses of 1 mm or greater; transmittance essentially zero in this wavelength range (argument presented on p. 597 of this reference that transmittance essentially zero in this wavelength range to 970 K); the applicable temperature is ambient, 293 K assigned; $\theta = 0^\circ$, $\theta' = 0^\circ$.

TABLE 9-18. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 1	
T = 293.	
2.00	0.852
2.50	0.375
2.80	0.607
3.00	0.895
4.90	0.937
6.80	0.875
7.50	0.790
7.60	0.529
8.20	0.388
9.00	0.241
9.40	0.056
10.0	0.025
10.9	0.037
11.5	0.000
50.0	0.000
CURVE 2	
T = 298.	
2.00	0.649
2.28	0.704
2.33	0.689
2.36	0.710
2.43	0.725
2.51	0.725
2.58	0.705
2.74	0.750
2.78	0.201
2.81	0.610
2.83	0.634
2.94	0.696
3.04	0.771
3.15	0.807
3.31	0.829
3.63	0.858
4.46	0.887
4.80	0.889
4.90	0.871
5.01	0.632

λ	τ
CURVE 2 (CONT.)	
5.05	0.619
5.08	0.853
5.14	0.883
5.24	0.899
5.98	0.898
6.28	0.655
6.49	0.819
6.53	0.783
6.68	0.567
6.76	0.663
6.80	0.700
6.93	0.733
7.07	0.732
7.25	0.692
7.34	0.641
7.46	0.631
7.55	0.579
7.59	0.505
7.69	0.516
7.99	0.367
8.06	0.337
8.15	0.315
8.78	0.123
8.99	0.074
9.21	0.046
9.49	0.025
9.73	0.014
10.0	0.000
12.0	0.000
CURVE 3	
T = 373.	
2.00	0.649
2.28	0.704
2.33	0.689
2.36	0.710
2.43	0.725
2.51	0.725
2.58	0.705

λ	τ
CURVE 3 (CONT.)	
2.74	0.750
2.78	0.201
2.81	0.610
2.83	0.684
2.94	0.696
3.04	0.771
3.15	0.807
3.31	0.829
3.63	0.858
4.46	0.887
4.80	0.889
4.90	0.871
5.01	0.632
5.08	0.647
5.14	0.878
5.29	0.896
5.92	0.896
6.12	0.877
6.44	0.811
6.57	0.762
6.69	0.574
6.76	0.657
6.93	0.698
7.07	0.698
7.21	0.667
7.37	0.608
7.42	0.605
7.57	0.534
7.65	0.466
7.73	0.466
7.96	0.329
8.06	0.273
8.18	0.270
8.52	0.165
8.83	0.039
8.99	0.058
9.26	0.028
9.49	0.017
10.0	0.000
12.0	0.000

λ	τ
CURVE 4	
T = 473.	
2.00	0.649
2.28	0.704
2.33	0.689
2.36	0.710
2.43	0.725
2.51	0.725
2.58	0.705
2.74	0.750
2.78	0.201
2.81	0.610
2.83	0.684
2.94	0.696
3.04	0.771
3.15	0.807
3.31	0.829
3.63	0.658
4.46	0.887
4.80	0.889
4.90	0.871
5.01	0.632
5.09	0.819
5.15	0.867
5.23	0.884
5.37	0.891
5.94	0.882
6.10	0.869
6.29	0.328
6.46	0.783
6.58	0.738
6.69	0.575
6.75	0.624
6.85	0.637
6.94	0.645
7.06	0.645
7.20	0.607
7.36	0.542
7.49	0.504
7.64	0.403
4.69	0.394

λ	τ
CURVE 4 (CONT.)	
7.88	0.324
8.02	0.231
8.33	0.162
8.65	0.087
8.85	0.054
9.09	0.026
9.42	0.013
10.0	0.000
12.0	0.000
CURVE 5	
T = 573.	
2.00	0.649
2.29	0.697
2.31	0.689
2.38	0.714
2.43	0.725
2.52	0.725
2.56	0.702
2.64	0.702
2.75	0.749
2.78	0.201
2.84	0.666
2.96	0.682
3.02	0.731
3.17	0.803
3.53	0.831
4.41	0.879
4.85	0.883
4.96	0.804
5.01	0.632
5.10	0.813
5.17	0.869
5.29	0.880
5.66	0.877
6.01	0.861
6.17	0.834
6.42	0.766
6.59	0.688

λ	τ
CURVE 5 (CONT.)	
6.70	0.575
6.83	0.594
7.02	0.597
7.15	0.569
7.38	0.466
7.60	0.374
7.63	0.341
7.74	0.320
8.06	0.174
8.49	0.087
8.77	0.046
9.03	0.021
9.50	0.000
12.0	0.000
CURVE 6	
T = 673.	
2.00	0.649
2.29	0.697
2.31	0.689
2.38	0.714
2.43	0.725
2.52	0.725
2.56	0.702
2.64	0.702
2.75	0.749
2.78	0.201
2.84	0.666
2.96	0.682
3.02	0.731
3.17	0.803
3.53	0.831
4.41	0.879
4.85	0.853
4.96	0.804
5.01	0.632
5.10	0.813
5.17	0.869
5.29	0.880

TABLE 9-16. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 6 (CONT.)	
5.68	0.872
5.89	0.859
6.18	0.814
6.33	0.776
6.45	0.742
6.56	0.679
6.64	0.609
6.70	0.567
7.01	0.553
7.24	0.491
7.50	0.371
7.87	0.203
8.04	0.141
8.24	0.103
8.50	0.064
8.77	0.038
9.00	0.018
9.50	0.000
12.0	0.000
CURVE 7	
T = 293.	
0.306	0.000
0.341	0.014
0.366	0.031
0.386	0.050
0.414	0.069
0.433	0.087
0.452	0.106
0.473	0.126
0.497	0.149
0.516	0.173
0.537	0.198
0.552	0.231
0.590	0.256
0.612	0.287
0.641	0.321
0.670	0.351
0.710	0.395
CURVE 7 (CONT.)	
0.752	0.436
0.827	0.482
0.877	0.534
0.921	0.577
0.995	0.627
1.07	0.668
1.13	0.699
1.21	0.729
1.28	0.760
1.36	0.738
1.43	0.809
1.50	0.825
1.61	0.844
1.75	0.662
1.90	0.679
2.08	0.893
2.19	0.900
2.32	0.907
2.62	0.907
2.70	0.887
2.74	0.716
2.80	0.402
2.84	0.880
2.91	0.902
3.06	0.898
CURVE 8	
T = 50.	
1.00	0.386
1.18	0.456
1.32	0.539
1.49	0.585
1.71	0.626
1.91	0.648
2.20	0.671
3.08	0.694
4.54	0.717
6.63	0.736
10.02	0.736
CURVE 8 (CONT.)	
10.99	0.716
11.60	0.716
11.85	0.723
12.11	0.723
12.47	0.696
12.73	0.688
13.48	0.688
13.67	0.657
13.94	0.657
14.14	0.622
14.49	0.426
14.64	0.269
14.70	0.118
14.79	0.051
15.00	0.372
CURVE 9	
T = 300.	
1.00	0.363
1.24	0.472
1.55	0.563
1.79	0.616
2.11	0.662
2.20	0.671
3.08	0.694
4.54	0.717
6.63	0.736
10.02	0.736
10.99	0.707
11.21	0.698
11.59	0.698
11.78	0.705
12.22	0.705
12.75	0.669
13.38	0.632
13.78	0.594
14.07	0.538
14.41	0.457
14.76	0.233
CURVE 9 (CONT.)	
14.92	0.116
15.00	0.116
CURVE 10	
T = 293.	
0.442	0.000
0.553	0.006
0.624	0.018
0.699	0.041
0.792	0.074
0.868	0.122
0.979	0.195
1.077	0.262
1.169	0.321
1.266	0.382
1.366	0.436
1.458	0.493
1.532	0.523
1.629	0.569
1.732	0.608
1.817	0.636
1.895	0.660
2.000	0.686
CURVE 11	
T = 293.	
2.00	0.670
2.11	0.698
2.15	0.688
2.20	0.715
2.24	0.715
2.28	0.705
2.33	0.733
2.38	0.737
2.45	0.737
2.51	0.718
2.56	0.730
2.63	0.737
CURVE 11 (CONT.)	
2.68	0.760
2.73	0.372
2.77	0.702
2.84	0.706
2.92	0.757
2.97	0.779
3.03	0.808
3.13	0.826
3.29	0.845
3.61	0.859
3.86	0.879
4.07	0.894
4.65	0.894
4.90	0.874
4.98	0.663
5.02	0.842
5.06	0.876
5.15	0.902
6.00	0.902
6.16	0.885
6.47	0.822
6.56	0.790
6.68	0.589
6.75	0.691
6.80	0.718
6.90	0.740
7.07	0.740
7.20	0.720
7.34	0.655
7.43	0.655
7.53	0.606
7.62	0.528
7.71	0.528
7.74	0.486
7.89	0.423
8.05	0.308
8.18	0.308
8.41	0.236
8.49	0.198
8.86	0.105
CURVE 11 (CONT.)	
9.07	0.069
9.45	0.037
9.77	0.023
10.28	0.000
CURVE 12	
T = 293.	
0.200	0.899
0.265	0.903
0.296	0.920
0.384	0.940
0.570	0.949
1.319	0.953
2.000	0.958
CURVE 13	
T = 293.	
2.00	0.943
3.96	0.943
5.35	0.949
5.84	0.940
6.14	0.927
6.45	0.905
6.74	0.867
7.17	0.790
7.45	0.722
7.65	0.604
8.22	0.485
8.45	0.409
8.65	0.340
8.83	0.259
8.99	0.202
9.19	0.149
9.42	0.097
9.63	0.065
9.59	0.041
10.32	0.025
10.65	0.000

TABLE 9-18. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 13 (CONT.)	
1.00	0.577
1.40	0.762
1.56	0.803
1.74	0.839
1.94	0.869
CURVE 14	
T = 50.	
1.00	0.577
1.40	0.762
1.56	0.803
1.74	0.839
1.94	0.869
2.17	0.895
2.55	0.895
2.63	0.908
2.68	0.908
2.73	0.884
2.74	0.778
2.79	0.854
2.93	0.687
3.02	0.910
3.14	0.924
3.44	0.933
4.25	0.946
4.61	0.951
4.92	0.946
4.97	0.854
5.03	0.816
5.08	0.953
6.33	0.953
6.19	0.941
6.30	0.917
6.41	0.892
6.54	0.874
6.62	0.861
6.64	0.843
6.68	0.728
6.72	0.779
CURVE 14 (CONT.)	
6.83	0.826
6.97	0.850
7.12	0.671
7.33	0.671
7.47	0.659
7.55	0.836
8.04	0.568
8.28	0.560
8.51	0.468
8.69	0.425
8.86	0.390
9.03	0.333
9.19	0.315
9.35	0.287
9.42	0.236
9.54	0.159
9.74	0.104
9.87	0.000
CURVE 15	
T = 300.	
1.00	0.577
1.40	0.762
1.56	0.803
1.74	0.839
1.94	0.869
2.17	0.895
2.55	0.895
2.63	0.908
2.68	0.908
2.73	0.884
2.74	0.676
2.82	0.841
3.02	0.896
3.14	0.924
3.44	0.938
4.25	0.946
4.61	0.951
4.92	0.948
CURVE 15 (CONT.)	
4.97	0.854
5.03	0.916
5.07	0.931
5.28	0.952
6.03	0.953
6.19	0.941
6.30	0.917
6.41	0.892
6.54	0.859
6.63	0.817
6.68	0.727
6.74	0.767
6.85	0.893
7.00	0.829
7.14	0.837
7.37	0.837
7.52	0.820
7.71	0.738
7.92	0.584
8.05	0.532
8.20	0.515
8.39	0.470
8.83	0.321
9.12	0.256
9.38	0.204
9.93	0.000
CURVE 16	
T = 299.	
1.00	0.233
1.16	0.353
1.38	0.489
1.48	0.541
1.63	0.600
1.79	0.666
2.04	0.730
2.24	0.771
2.46	0.806
2.58	0.806
CURVE 16 (CONT.)	
2.65	0.777
2.75	0.652
2.79	0.817
2.92	0.838
3.13	0.859
3.49	0.878
3.98	0.901
4.51	0.922
5.05	0.936
5.73	0.936
6.15	0.921
6.46	0.905
6.76	0.870
7.06	0.835
7.27	0.788
7.50	0.736
7.69	0.685
7.90	0.622
8.14	0.554
8.36	0.475
8.61	0.372
8.88	0.265
9.04	0.207
9.17	0.166
9.36	0.122
9.60	0.074
9.80	0.041
10.00	0.019
CURVE 17	
T = 673.	
1.00	0.233
1.16	0.353
1.38	0.489
1.48	0.541
1.63	0.600
1.79	0.665
2.04	0.730
2.24	0.771
CURVE 17 (CONT.)	
2.46	0.806
2.58	0.806
2.65	0.777
2.75	0.652
2.79	0.817
2.92	0.836
3.13	0.859
3.49	0.876
3.98	0.901
4.51	0.922
5.05	0.936
5.73	0.936
5.93	0.919
6.16	0.895
6.37	0.846
6.61	0.792
6.87	0.741
7.06	0.685
7.32	0.605
7.63	0.521
7.84	0.450
8.09	0.346
8.34	0.268
8.57	0.197
8.81	0.143
9.05	0.085
9.28	0.034
9.45	0.000
CURVE 18	
T = 873.	
1.00	0.233
1.16	0.353
1.38	0.489
1.48	0.541
1.63	0.600
1.79	0.666
2.04	0.730
2.24	0.771
CURVE 18 (CONT.)	
2.46	0.806
2.58	0.806
2.65	0.777
2.75	0.652
2.79	0.817
2.92	0.838
3.13	0.859
3.49	0.878
3.98	0.901
4.51	0.922
5.05	0.936
5.63	0.936
5.81	0.921
5.99	0.896
6.19	0.859
6.41	0.810
6.59	0.766
6.77	0.711
6.97	0.655
7.12	0.608
7.33	0.533
7.51	0.467
7.68	0.404
7.84	0.347
8.02	0.287
8.17	0.237
8.38	0.179
8.59	0.125
8.79	0.084
9.00	0.045
9.13	0.000
CURVE 19	
T = 1073.	
1.00	0.233
1.16	0.353
1.38	0.489
1.48	0.541
1.63	0.600

TABLE 9-16. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 19(CONT.)		CURVE 20(CONT.)		CURVE 20(CONT.)		CURVE 21(CONT.)		CURVE 21(CONT.)		CURVE 22(CONT.)	
1.79	0.666	0.83	0.780	7.50	0.844	2.31	0.902	7.84	0.256	2.43	0.678
2.04	0.730	0.89	0.802	7.54	0.833	2.42	0.907	7.87	0.200	2.60	0.881
2.24	0.771	0.94	0.821	7.59	0.813	2.55	0.907	7.90	0.166	2.71	0.868
2.46	0.806	0.99	0.838	7.63	0.777	2.62	0.912	7.92	0.139	2.73	0.726
2.53	0.806	1.08	0.850	7.70	0.680	2.67	0.894	7.94	0.115	2.73	0.785
2.65	0.777	1.16	0.864	7.78	0.580	2.70	0.879	7.98	0.094	2.76	0.816
2.75	0.652	1.26	0.674	7.83	0.487	2.71	0.850	8.03	0.073	2.80	0.842
2.79	0.817	1.35	0.884	7.86	0.426	2.73	0.764	8.05	0.063	2.86	0.855
2.92	0.838	1.45	0.890	7.89	0.399	2.73	0.813	8.11	0.053	2.95	0.865
3.13	0.859	1.59	0.897	7.95	0.343	2.77	0.866	8.17	0.042	3.03	0.872
3.49	0.878	1.66	0.906	8.01	0.304	2.79	0.878	8.26	0.030	3.10	0.878
3.98	0.901	2.01	0.910	8.06	0.277	2.86	0.894	8.35	0.021	3.19	0.883
4.51	0.922	2.44	0.916	8.12	0.255	2.92	0.900	8.51	0.000	3.27	0.888
5.05	0.936	2.63	0.916	8.25	0.223	3.05	0.906			3.38	0.892
5.43	0.936	2.65	0.904	8.38	0.191	3.49	0.909	CURVE 22		3.49	0.897
5.64	0.917	2.71	0.880	8.49	0.165	3.80	0.912	T = 293.		3.80	0.893
5.81	0.901	2.72	0.817	8.58	0.134	3.99	0.914			3.98	0.699
6.02	0.870	2.72	0.683	8.72	0.093	4.49	0.921	0.50	0.100	4.46	0.900
6.25	0.801	2.75	0.902	8.77	0.083	4.77	0.925	0.60	0.203	4.68	0.900
6.42	0.754	2.81	0.910	8.91	0.063	5.07	0.931	0.68	0.331	4.78	0.904
6.65	0.685	2.88	0.913	9.02	0.044	5.27	0.933	0.76	0.453	4.88	0.909
6.96	0.579	3.00	0.916	9.17	0.000	5.68	0.933	0.79	0.508	4.95	0.903
7.25	0.474	3.49	0.919			5.93	0.927	0.82	0.550	5.01	0.903
7.52	0.359	3.80	0.921	CURVE 21		6.09	0.922	0.86	0.581	5.13	0.912
7.69	0.308	3.85	0.921	T = 293.		6.26	0.914	0.91	0.614	5.23	0.916
7.84	0.254	4.35	0.925			6.50	0.896	0.96	0.645	5.32	0.918
8.07	0.190	4.69	0.932	0.50	0.322	6.98	0.851	1.08	0.701	5.59	0.915
8.22	0.147	4.93	0.937	0.76	0.598	7.10	0.838	1.14	0.721	5.69	0.914
8.41	0.102	4.99	0.933	0.82	0.648	7.20	0.824	1.22	0.747	5.79	0.910
8.58	0.059	5.18	0.940	0.89	0.701	7.28	0.803	1.29	0.763	5.87	0.905
8.71	0.031	5.70	0.940	0.92	0.722	7.35	0.794	1.34	0.778	6.00	0.895
8.84	0.000	6.00	0.935	1.00	0.750	7.43	0.774	1.40	0.791	6.15	0.880
		6.25	0.930	1.10	0.779	7.47	0.757	1.50	0.807	6.34	0.859
CURVE 20		6.50	0.923	1.19	0.800	7.53	0.734	1.59	0.819	6.50	0.838
T = 293.		6.63	0.917	1.32	0.823	7.56	0.702	1.68	0.831	6.67	0.812
		6.87	0.908	1.42	0.841	7.63	0.616	1.79	0.841	6.82	0.790
0.50	0.560	7.06	0.698	1.50	0.853	7.70	0.514	1.88	0.848	6.99	0.761
0.60	0.637	7.21	0.887	1.63	0.867	7.74	0.442	2.00	0.857	7.10	0.739
0.69	0.701	7.34	0.876	1.73	0.873	7.78	0.385	2.11	0.862	7.18	0.716
0.77	0.751	7.41	0.865	2.14	0.892	7.81	0.302	2.30	0.872	7.25	0.698

TABLE 9-16. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 22 (CONT.)		CURVE 23 (CONT.)		CURVE 23 (CONT.)		CURVE 24 (CONT.)		CURVE 24 (CONT.)		CURVE 25 (CONT.)	
7.29	0.686	2.59	0.867	7.41	0.537	2.69	0.733	7.46	0.250	3.33	0.745
7.35	0.655	2.63	0.867	7.47	0.501	2.70	0.647	7.52	0.200	3.39	0.757
7.39	0.643	2.71	0.859	7.51	0.459	2.74	0.701	7.62	0.101	3.49	0.771
7.43	0.619	2.72	0.817	7.57	0.373	2.77	0.723	7.68	0.055	3.55	0.780
7.48	0.591	2.73	0.714	7.65	0.239	2.81	0.746	7.74	0.000	3.66	0.786
7.52	0.557	2.73	0.771	7.73	0.127	2.86	0.762	CURVE 25		3.76	0.790
7.54	0.529	2.81	0.816	7.76	0.099	2.91	0.778	T = 293.		3.80	0.792
7.58	0.479	2.83	0.828	7.78	0.069	2.99	0.794	0.84	0.000	3.85	0.794
7.63	0.433	2.87	0.836	7.82	0.044	3.06	0.808	1.01	0.073	4.01	0.799
7.70	0.255	2.92	0.847	7.84	0.029	3.13	0.821	1.20	0.157	4.55	0.799
7.74	0.194	2.99	0.858	7.90	0.000	3.20	0.830	1.39	0.242	4.66	0.797
7.76	0.138	3.03	0.865	CURVE 24		3.27	0.837	1.50	0.292	4.77	0.793
7.81	0.101	3.20	0.874	T = 293.		3.34	0.845	1.66	0.363	4.84	0.788
7.85	0.072	3.32	0.882	0.65	0.000	3.44	0.849	1.85	0.434	4.88	0.773
7.89	0.046	3.49	0.888	0.71	0.093	3.54	0.854	1.97	0.484	4.92	0.755
7.92	0.031	3.70	0.895	0.76	0.141	3.71	0.861	2.09	0.539	4.97	0.733
8.32	0.000	3.80	0.895	0.83	0.199	3.80	0.863	2.15	0.566	5.01	0.710
CURVE 23		4.43	0.895	0.98	0.308	4.21	0.862	2.24	0.597	5.03	0.737
T = 293.		4.54	0.892	1.08	0.376	4.58	0.859	2.39	0.644	5.04	0.753
0.58	0.056	4.69	0.892	1.14	0.417	4.70	0.857	2.46	0.665	5.07	0.768
0.59	0.122	4.85	0.897	1.27	0.485	4.85	0.853	2.50	0.678	5.11	0.777
0.70	0.247	5.02	0.897	1.36	0.531	4.90	0.847	2.54	0.684	5.15	0.782
0.75	0.314	5.14	0.904	1.43	0.563	4.97	0.821	2.61	0.688	5.19	0.786
0.80	0.401	5.22	0.910	1.51	0.594	5.07	0.860	2.69	0.684	5.23	0.787
0.83	0.447	5.52	0.910	1.58	0.618	5.15	0.871	2.70	0.647	5.35	0.787
0.86	0.488	5.65	0.908	1.65	0.643	5.28	0.871	2.73	0.500	5.44	0.782
0.93	0.558	5.78	0.903	1.74	0.668	5.43	0.865	2.74	0.455	5.55	0.771
0.97	0.589	5.87	0.898	1.84	0.694	5.61	0.853	2.77	0.500	5.64	0.761
1.09	0.642	6.00	0.883	1.94	0.716	5.79	0.837	2.80	0.524	5.71	0.749
1.29	0.715	6.15	0.854	2.02	0.735	5.88	0.825	2.83	0.551	5.79	0.733
1.39	0.748	6.27	0.845	2.14	0.757	5.99	0.804	2.86	0.575	5.90	0.701
1.50	0.774	6.45	0.810	2.29	0.785	6.10	0.779	2.91	0.602	6.00	0.670
1.59	0.792	6.61	0.774	2.36	0.799	6.21	0.747	2.96	0.630	6.05	0.651
1.67	0.803	6.88	0.714	2.42	0.806	6.67	0.599	3.04	0.662	6.13	0.618
1.76	0.813	7.01	0.685	2.51	0.814	7.02	0.485	3.09	0.684	6.23	0.575
2.01	0.835	7.06	0.672	2.58	0.814	7.10	0.457	3.16	0.703	6.33	0.529
2.22	0.846	7.16	0.645	2.65	0.801	7.19	0.415	3.20	0.715	6.49	0.453
2.43	0.860	7.23	0.620	2.68	0.782	7.26	0.380	3.27	0.732	6.58	0.405
		7.28	0.599			7.32	0.348			6.63	0.378
		7.36	0.556			7.39	0.300			6.68	0.352

TABLE 9-18. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

CURVE 25 (CONT.)

λ	τ
6.72	0.328
6.80	0.300
6.88	0.273
7.00	0.237
7.09	0.236
7.19	0.173
7.28	0.144
7.33	0.126
7.45	0.071
7.59	0.000

CURVE 26
T = 293.

λ	τ
1.00	0.676
1.16	0.759
1.29	0.805
1.42	0.828
1.70	0.871
1.98	0.900
2.20	0.915
2.57	0.915
2.63	0.882
2.65	0.773
2.67	0.755
2.71	0.780
2.73	0.891
2.94	0.912
3.32	0.933
3.79	0.945
4.03	0.945
4.12	0.935
4.18	0.917
4.33	0.948
4.79	0.943
4.88	0.935
4.96	0.917
5.01	0.937
5.14	0.949
5.61	0.949

CURVE 26 (CONT.)

λ	τ
5.96	0.939
6.24	0.919
6.49	0.888
6.72	0.853
6.89	0.874
7.01	0.874
7.21	0.852
7.41	0.823
7.52	0.801
7.60	0.776
7.70	0.655
7.82	0.550
7.84	0.495
7.92	0.441
8.04	0.421
8.17	0.421
8.26	0.394
8.41	0.335
8.57	0.286
8.62	0.225
9.00	0.169

CURVE 27
T = 293.

λ	τ
1.01	0.270
1.08	0.344
1.16	0.429
1.35	0.534
1.57	0.634
1.67	0.742
2.11	0.783
2.37	0.819
2.58	0.819
2.64	0.802
2.69	0.684
2.71	0.636
2.79	0.739
2.89	0.813
3.00	0.854

CURVE 27 (CONT.)

λ	τ
3.19	0.882
3.43	0.907
3.65	0.918
3.80	0.918
4.37	0.918
4.62	0.913
4.76	0.902
4.84	0.874
4.89	0.831
4.95	0.895
5.02	0.919
5.16	0.930
5.31	0.930
5.78	0.917
5.99	0.896
6.13	0.866
6.24	0.823
6.37	0.767
6.61	0.624
6.73	0.671
6.84	0.690
6.99	0.690
7.13	0.671
7.33	0.572
7.52	0.441
7.73	0.214
7.87	0.082
7.99	0.047
8.19	0.047
8.34	0.035
8.50	0.016
9.00	0.000

CURVE 28
T = 293.

λ	τ
1.00	0.072
1.18	0.190
1.33	0.304
1.47	0.384

CURVE 28 (CONT.)

λ	τ
1.63	0.469
1.83	0.539
2.03	0.618
2.21	0.671
2.32	0.699
2.45	0.715
2.54	0.715
2.62	0.697
2.66	0.629
2.66	0.556
2.73	0.582
2.73	0.601
2.78	0.623
2.90	0.649
2.94	0.720
3.01	0.755
3.12	0.796
3.21	0.829
3.34	0.854
3.55	0.863
3.80	0.866
4.10	0.866
4.17	0.848
4.24	0.823
4.29	0.842
4.37	0.863
4.85	0.863
4.90	0.672
5.02	0.830
5.14	0.876
5.49	0.876
5.72	0.861
5.91	0.828
6.06	0.800
6.14	0.762
6.29	0.674
6.58	0.469
6.65	0.410
6.69	0.380
6.79	0.429

CURVE 28 (CONT.)

λ	τ
6.89	0.457
6.96	0.468
7.06	0.468
7.15	0.454
7.21	0.429
7.43	0.268
7.54	0.153
7.66	0.066
7.70	0.032
7.85	0.010
9.00	0.005

CURVE 29
T = 293.

λ	τ
0.93	0.295
1.60	0.491
2.25	0.610
2.50	0.638
2.82	0.645
2.96	0.630
3.11	0.623
3.40	0.647
4.19	0.718
5.02	0.738
5.87	0.742
5.97	0.744
6.52	0.748
6.84	0.655
7.14	0.539
7.42	0.402
7.66	0.241
7.79	0.138
7.85	0.073
7.93	0.031
8.03	0.018
8.26	0.000

CURVE 30
T = 293.

λ	τ
10.	0.0
11.	0.0
12.	0.0
13.	0.0
14.	0.0
15.	0.0

h. Normal Spectral Transmittance (Temperature Dependence)

No experimental data was found for the temperature dependence of the normal spectral transmittance of Irtran 1. However, a provisional curve at 3.8 μm, with an uncertainty of 12%, and applying to a specimen thickness of 1.75 mm is listed in Table 9-19 and shown in Figure 9-13. Several considerations were relevant in arriving at this provisional curve. The data of curves 16, 17, 18, and 19 of the previous section show the transmittance as constant at temperatures of 299, 673, 873, and 1073 K. The uncertainty of 12% takes account of the slight variation at 3.8 μm by curves 2-6 of the previous section. The constant value selected at 3.8 μm was the value from the provisional curve in the preceding section.

TABLE 9-19. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (IRTRAN 1) (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

T	τ
1.75MM THICK	
λ = 3.8	
299.	0.898
673.	0.898
873.	0.898
1073.	0.898

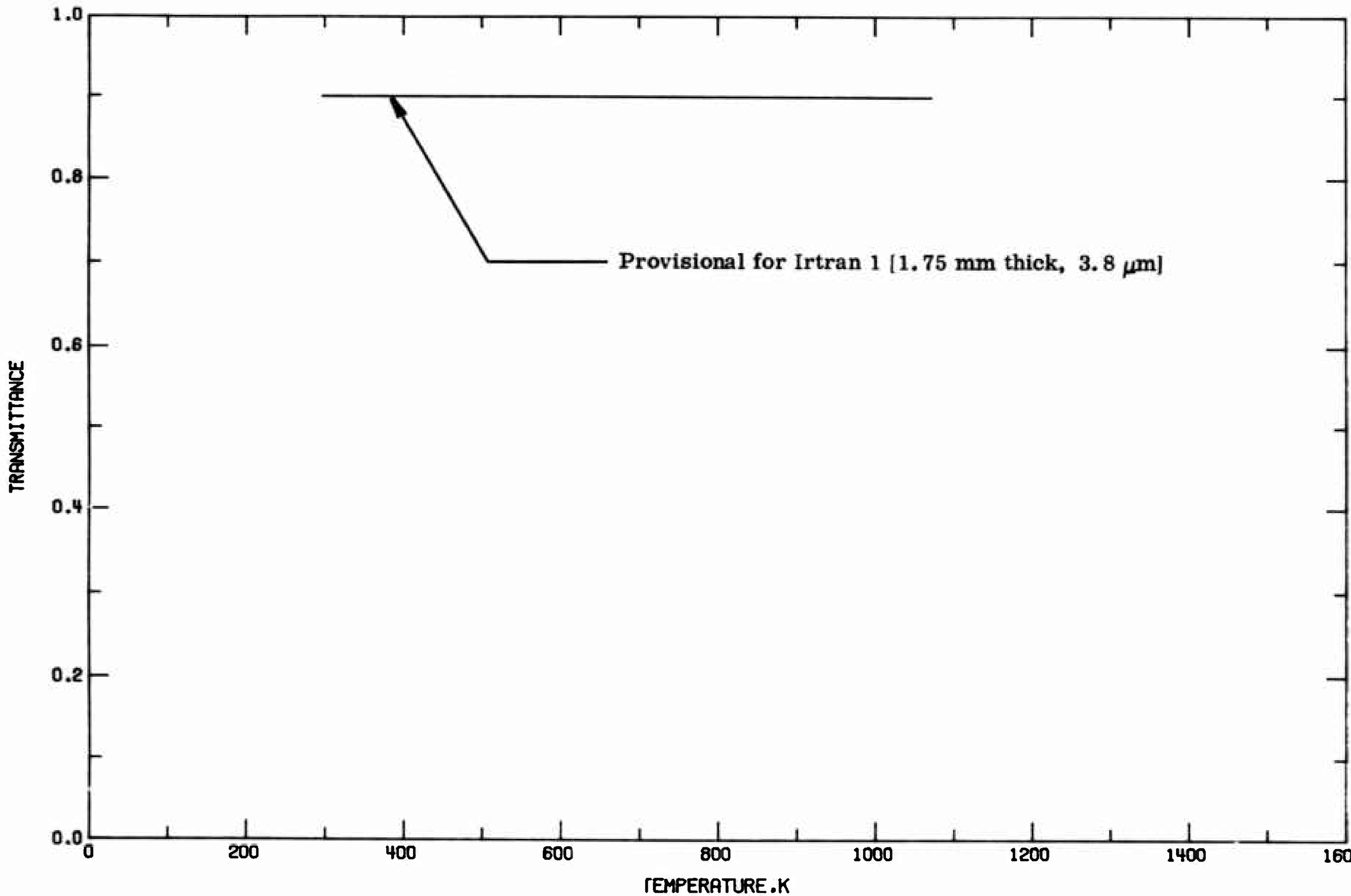


FIGURE 9-13. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF MAGNESIUM FLUORIDE (TEMPERATURE DEPENDENCE).

4.10. Pyroceram

Pyroceram is a generic name for a group of glass-ceramic materials, which were developed by the Corning Glass Works, Corning, New York 14830. The word "Pyroceram" is a trademark of Corning Glass Works and is registered with the United States Patent Office. Pyrocerams are microcrystalline materials formed originally from a noncrystalline glass.

The specific Pyroceram that is of interest for the purposes of this report is Corning Code 9606, therefore, specific properties mentioned in this general section will be for Corning 9606. In addition, in the data sections pertaining to Pyroceram, the aim is to give evaluated data, when appropriate, for Corning 9606. Data was extracted not only for Corning 9606 but also for any other material subsumed under the name of Pyroceram or that was labeled as a Pyroceramic type material. This was done in order to see the similarities and differences of the various Pyrocerams with the purpose of aiding data evaluation.

Corning Code 9606 is a magnesia aluminosilicate glass ceramic (composed of silicon dioxide, aluminum oxide, magnesium oxide, and a small amount of titanium dioxide). The ingredients are melted together at temperatures of the order of 1900 K using special techniques to insure uniform composition, constant density, freedom from bubbles and striations, and uniform electrical properties. Pyroceram 9606 is non-porous, considerably harder than glass, opaque, and gray in color.

Code 9606 is primarily used in military products and specifically as missile radomes since it has uniform electrical properties throughout the material at elevated temperatures and the ability to pass R.F. signals. Other properties which make it good for radome applications are good thermal shock and rain erosion characteristics.

According to 9606 Data Sheets [A00009], its physical properties include a softening point of 1623 K, a density of 2.6 g/cm^3, a porosity (void volume) of 0.00%, water absorption of 0.00%, and the property of being impermeable to gas. Mechanical properties of Corning Code 9606 include a strength to weight ratio (modulus of rupture to specific gravity) of 13.5×10^3 psi at 293 K, Young's modulus of 17.4×10^6 psi at 293 K, a shear modulus of 6.9×10^6 psi at 293 K, Poisson's ratio of 0.245 at 293 K, a modulus of rupture of 35×10^3 psi at 293 K, a Knoop hardness of 619 kg/mm^2 with a 500 gram load, and a Knoop hardness of 698 kg/mm^2 with a 100 gram load. Thermal properties include a coefficient of linear expansion of 57×10^{-7} C^{-1} over a temperature range of 293 to 593 K, a mean thermal conductivity of 0.034 W cm^{-1} C^{-1} over a temperature range of 293 to 1093 K, a mean thermal diffusivity of 0.0127 cm^2 s^{-1} over a temperature range of 293 to 1093 K, and a

mean specific heat of 0.233 cal g^{-1} C^{-1} over the temperature range of 298 to 673 K. Electrical properties include a loss factor of 0.8% at 293 K and a dielectric strength of 350 volts rms mil^{-1} at 293 K and 60 cps.

a. Normal Spectral Emittance (Wavelength Dependence)

There are four sets of experimental data available for the wavelength dependence of the normal spectral emittance of Corning 9606 as listed in Table 10-2 and shown in Figure 10-1. Specimen characterization and measurement information for the data are given in Table 10-1.

The data for Corning 9606 covers a temperature range of 813 to 1403 K. Four sets of experimental also are available for another kind of Pyroceram known as Corning 9608 which shows the same general trend as Corning 9606, but the values are different enough that using data of Corning 9608 to help in generating evaluated data for Corning 9606 is not justified.

It is noted that the data for Corning 9606 are widely separated and, therefore, there is not enough factual evidence to justify giving evaluated values.

The lines in Figure 10-1 connecting the data points are not meant to imply that they represent a smooth curve. The data for all eight curves in Figure 10-1 and Tables 10-1 and 10-2 were extracted from tabular data. A smooth curve should not be drawn through the data points because of the widely spaced nature of the data. In addition, it is not justified to generate values for a plot of normal spectral emittance as a function of temperature for 3.8 and 10.6 μm.

Data for the wavelength dependence of the normal spectral emittance of Corning 9606 below 813 K and above 1403 K were not located.

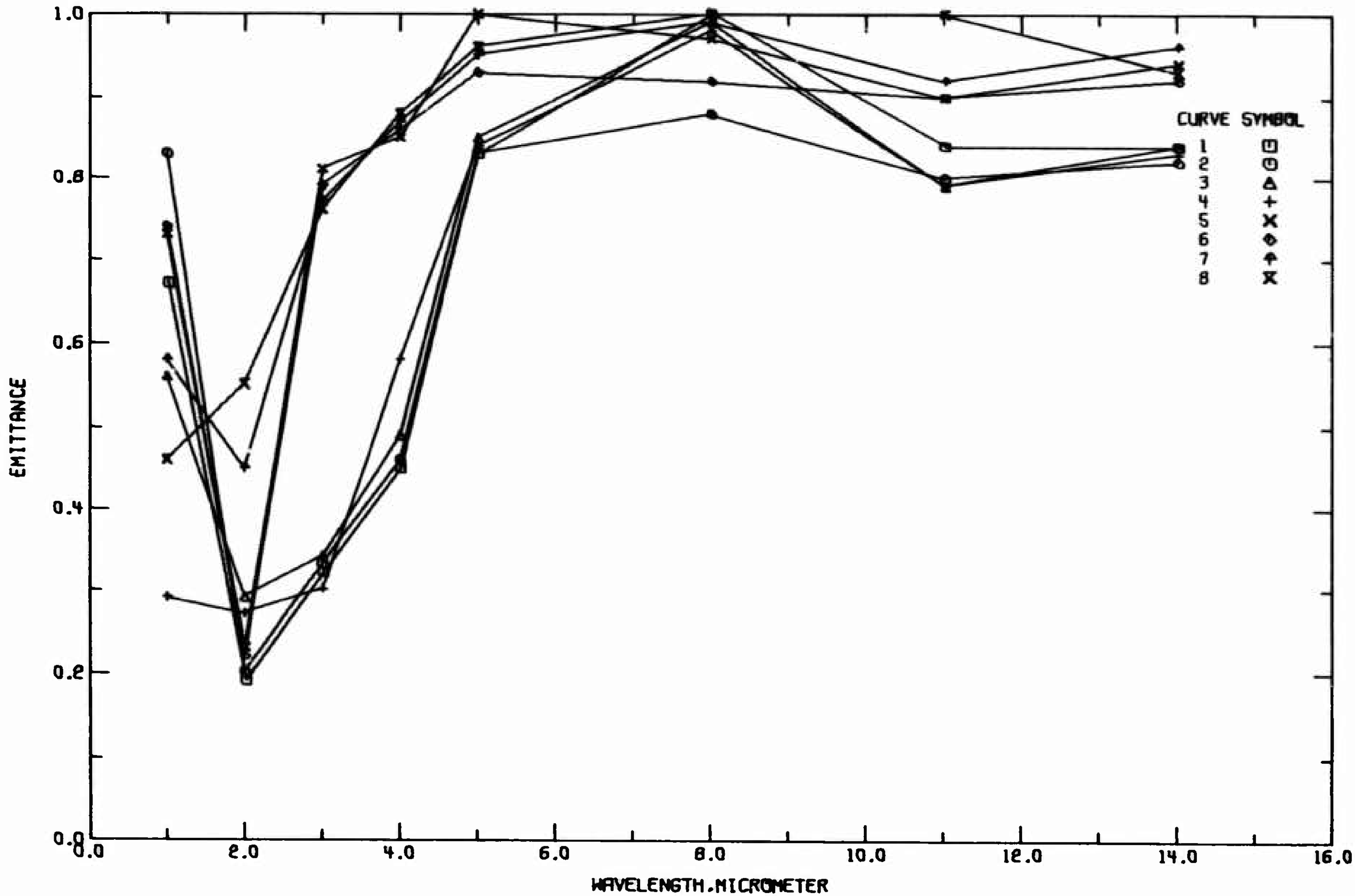


FIGURE 10-1. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF PYROCERAM (WAVELENGTH DEPENDENCE).

TABLE 10-1. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF PYROCERAM (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T29570	Folweiler, R.C.	1964	1-14	813	Corning 9606	Method of measurement used was rotating sample method: rotating specimen in furnace used in conjunction with Baird-Atomic infrared spectrometer, model NK-1A, for emittance measurement; $\theta' \sim 0°$, reported error ±10.
2	T29570	Folweiler, R.C.	1964	1-14	1021	Corning 9606	The above specimen.
3	T29570	Folweiler, R.C.	1964	1-14	1205	Corning 9606	The above specimen.
4	T29570	Folweiler, R.C.	1964	1-14	1403	Corning 9606	The above specimen.
5	T29570	Folweiler, R.C.	1964	1-14	813	Corning 9608	Method of measurement used was rotating sample method: rotating specimen in furnace used in conjunction with Baird-Atomic infrared spectrometer, model NK-1A, for emittance measurement; value reported at 5 μ of 1.04 obviously in error, it cannot be greater than 1.0; $\theta \sim 0°$, reported error ±10.
6	T29570	Folweiler, R.C.	1964	1-14	1018	Corning 9608	The above specimen.
7	T29570	Folweiler, R.C.	1964	1-14	1205	Corning 9608	The above specimen.
8	T29570	Folweiler, R.C.	1964	1-14	1405	Corning 9608	The above specimen except value reported at 11 μ of 1.04 obviously in error, it cannot be greater than 1.0.

TABLE 10-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF PYROCERAM (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 1	
T = 813.	
1.	0.67
2.	0.19
3.	0.32
4.	0.45
5.	0.83
8.	1.00
11.	0.34
14.	0.84
CURVE 2	
T = 1021.	
1.	0.83
2.	0.20
3.	0.33
4.	0.46
5.	0.83
8.	0.88
11.	0.30
14.	0.82
CURVE 3	
T = 1205.	
1.	0.56
2.	0.29
3.	0.34
4.	0.49
5.	0.35
8.	0.99
11.	0.79
14.	0.84
CURVE 4	
T = 1403.	
1.	0.29
2.	0.27
3.	0.30
CURVE 4 (CONT.)	
4.	0.58
5.	0.84
8.	0.98
11.	0.79
14.	0.83
CURVE 5	
T = 813.	
1.	0.73
2.	0.23
3.	0.81
4.	0.85
5.	1.0
8.	0.97
11.	0.90
14.	0.94
CURVE 6	
T = 1018.	
1.	0.74
2.	0.22
3.	0.79
4.	0.66
5.	0.93
8.	0.92
11.	0.90
14.	0.92
CURVE 7	
T = 1205.	
1.	0.58
2.	0.45
3.	0.77
4.	0.67
5.	0.95
8.	0.99
11.	0.92
CURVE 7 (CONT.)	
14.	0.96
CURVE 8	
T = 1405.	
1.	0.46
2.	0.55
3.	0.76
4.	0.88
5.	0.96
8.	1.00
11.	1.0
14.	0.93

b. Normal Spectral Emittance (Temperature Dependence)

There is one set of experimental data available for the temperature dependence of the normal spectral emittance of Corning 9606 as well as three sets for Corning 9608. These data sets are tabulated in Table 10-4 and shown graphically in Figure 10-2. The specimen characterization and measurement information are given in Table 10-3.

The one data set for Corning 9606 covers a temperature range of 1191 to 1456 K and for a wavelength of 0.665 μm. Because of the lack of data at 3.8 and 10.6 μm, no evaluated values can be given.

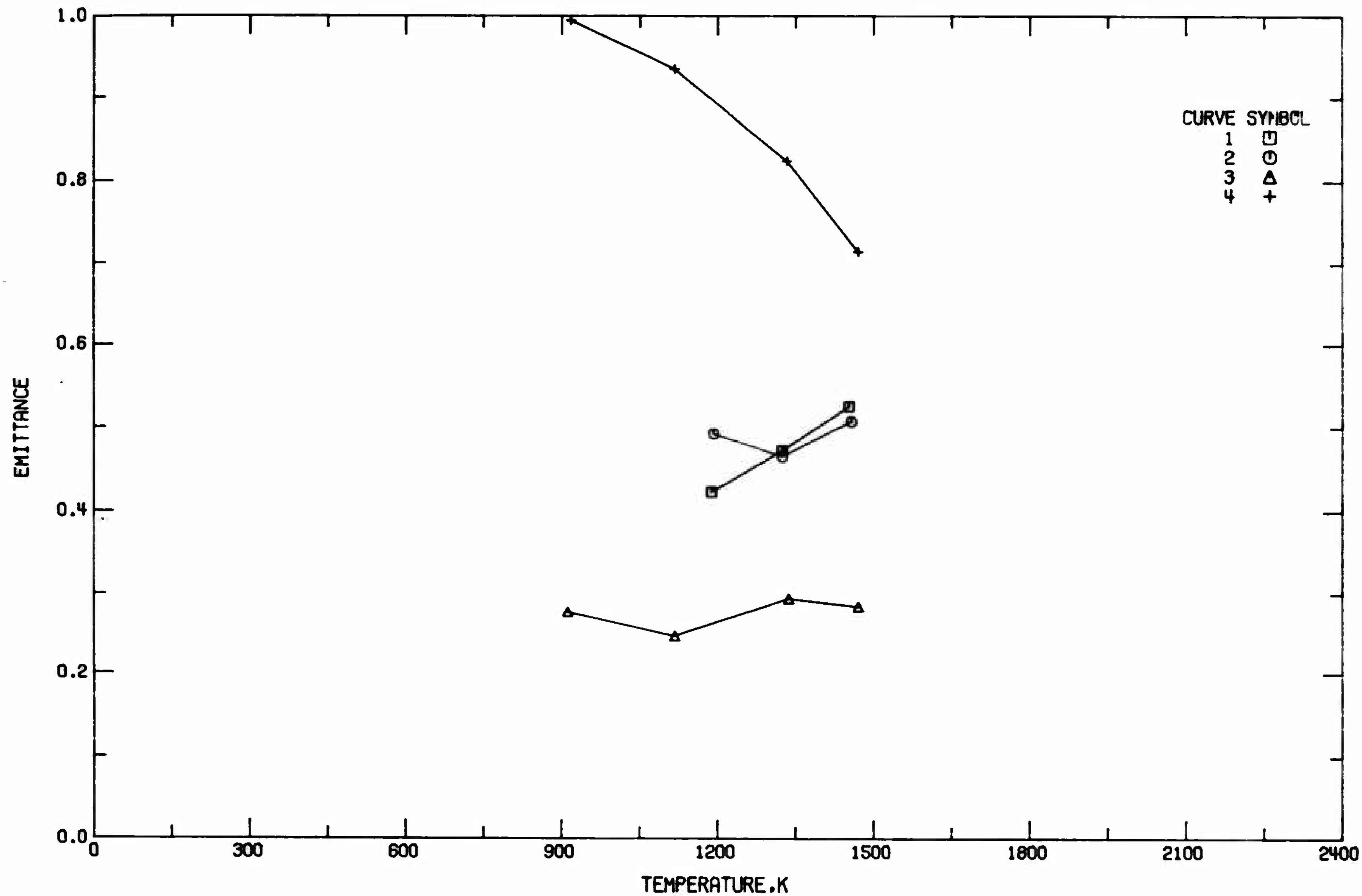


FIGURE 10-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF PYROCERAM (TEMPERATURE DEPENDENCE).

TABLE 10-3. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF PYROCERAM (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T10060	Olson, O.H. and Morris, J.C.	1959	0.665	1191-1456	Pyroceram 9606	Data from figure; $\theta'=0°$.
2	T10060	Olson, O.H. and Morris, J.C.	1959	0.665	1195-1460	Pyroceram 9608	Data from figure; $\theta'=0°$.
3	T18630	Blair, G.R.	1960	0.640		Corning body 9608	Ground to size, ultrasonically cleaned, surface polished with 1-5 μm diamond polishing compound until normally mat surface began to reflect light, cleaned, polished with cloth charged with a paste of cerium oxide and Kerosene; measured in vacuum; data from figure; emissivity reported; $\theta'=0°$, reported error ~10%.
4	T18630	Blair, G.R.	1960	1		Corning body 9608	The above specimen.

TABLE 10-4. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF PYROCERAM (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ
CURVE 1 λ = 0.665	
1191.	0.423
1327.	0.472
1456.	0.525
CURVE 2 λ = 0.665	
1195.	0.492
1327.	0.465
1460.	0.507
CURVE 3 λ = 0.640	
913.	0.277
1119.	0.247
1339.	0.294
1473.	0.284
CURVE 4 λ = 1.	
919.	0.993
1119.	0.934
1336.	0.824
1473.	0.714

c. Normal Spectral Reflectance (Wavelength Dependence)

There is one set of experimental data applicable to Corning 9606 and one to Corning 9608 for the wavelength dependence of normal spectral reflectance as listed in Table 10-7 and shown in Figures 10-3 and 10-4. Specimen characterization and measurement information for the data are given in Table 10-6. The data obtained by Olson and Morris [T10060] (curve 1) is applicable only at room temperature and only covers the wavelength range of 0.30 to 2.7 μm. Confirmatory data for Corning 9606 over this wavelength range is lacking and no data has been found in the wavelength range of 2.7 to 15 μm. In addition, no data was located above room temperature for any portion of the wavelength range of interest.

Provisional values for Corning 9606 are listed in Table 10-5 and shown in Figure 10-3. The structure was kept at 1.36 and 1.78 μm because Corning 9608 also shows this structure which indicates the structure is characteristic of the Pyroceram class of materials.

The context within which this set of provisional values is valid is the following: (1) they hold for room temperature, 293 K, (2) the geometrical conditions are that incidence is for near normal, specifically $\theta = 9^\circ$, while the viewed conditions are over a hemisphere, i.e., 2π, and (3) the wavelength range covered is from 0.3 to 2.7 μm. The estimate of the uncertainty is that for wavelengths between 0.35 and 2.7 μm it is thought to be of the order of 10% and for wavelengths less than 0.35 μm it would be larger in percentage value.

TABLE 10-5. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF PYROCERAM (CORNING 9606) (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ	λ	ρ
T = 293		T = 293 (CONT.)	
0.297	0.062	2.1	0.939
0.318	0.142	2.12	0.938
0.339	0.224	2.2	0.933
0.446	0.529	2.32	0.925
0.480	0.582	2.3	0.926
0.5	0.588	2.39	0.919
0.516	0.593	2.4	0.915
0.6	0.612	2.45	0.890
0.639	0.619	2.5	0.862
0.7	0.638	2.51	0.852
0.710	0.642	2.59	0.819
0.795	0.700	2.6	0.817
0.8	0.706	2.68	0.791
0.9	0.770	2.7	0.786
0.952	0.800	2.72	0.780
1.0	0.817		
1.05	0.835		
1.1	0.844		
1.16	0.852		
1.2	0.854		
1.21	0.854		
1.28	0.854		
1.3	0.853		
1.35	0.850		
1.4	0.853		
1.41	0.855		
1.49	0.889		
1.5	0.896		
1.58	0.915		
1.6	0.917		
1.64	0.912		
1.7	0.899		
1.77	0.891		
1.8	0.894		
1.83	0.900		
1.9	0.923		
1.94	0.934		
1.99	0.944		
2.0	0.944		

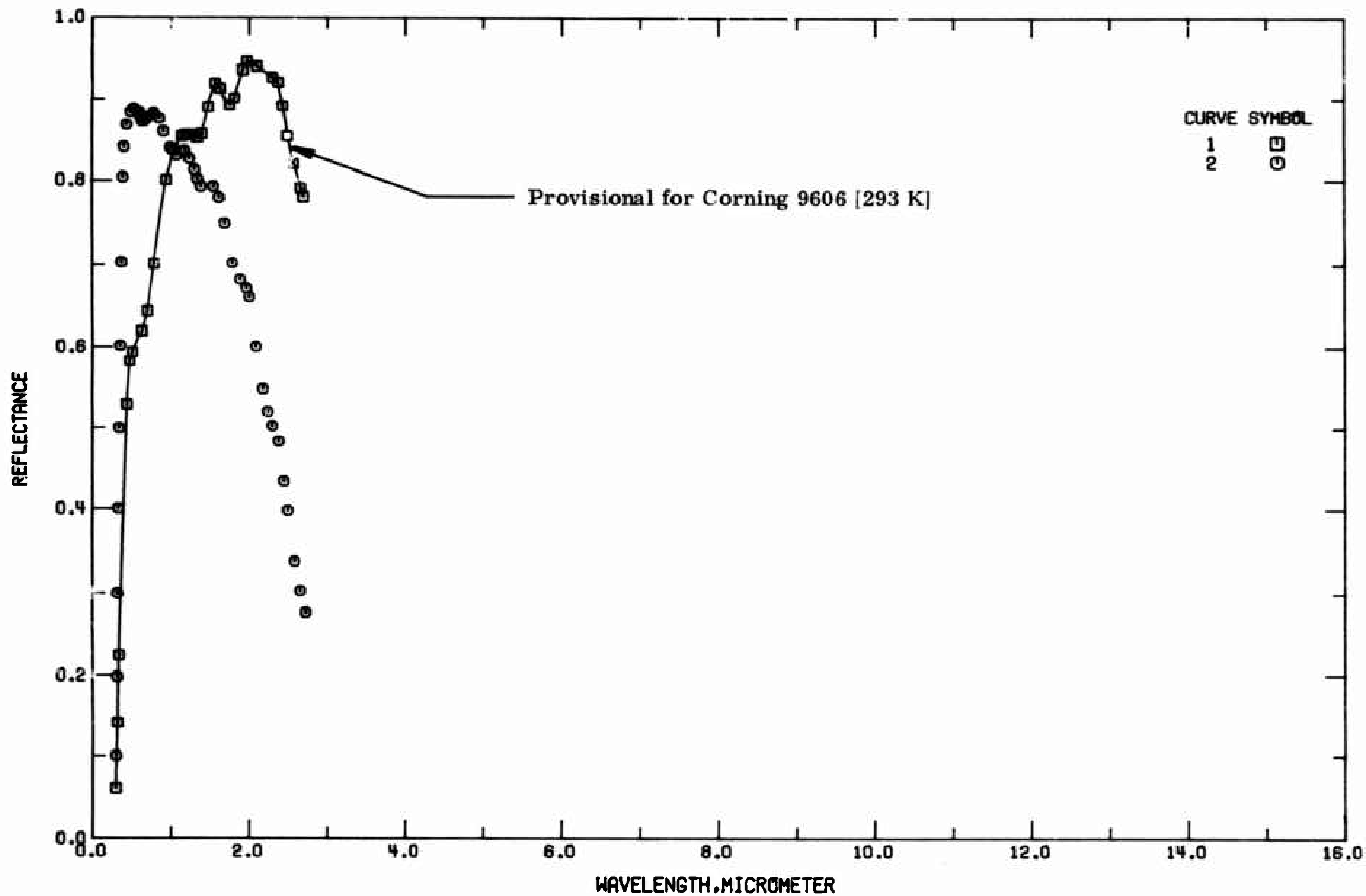


FIGURE 10-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF PYROCERAM (WAVELENGTH DEPENDENCE).

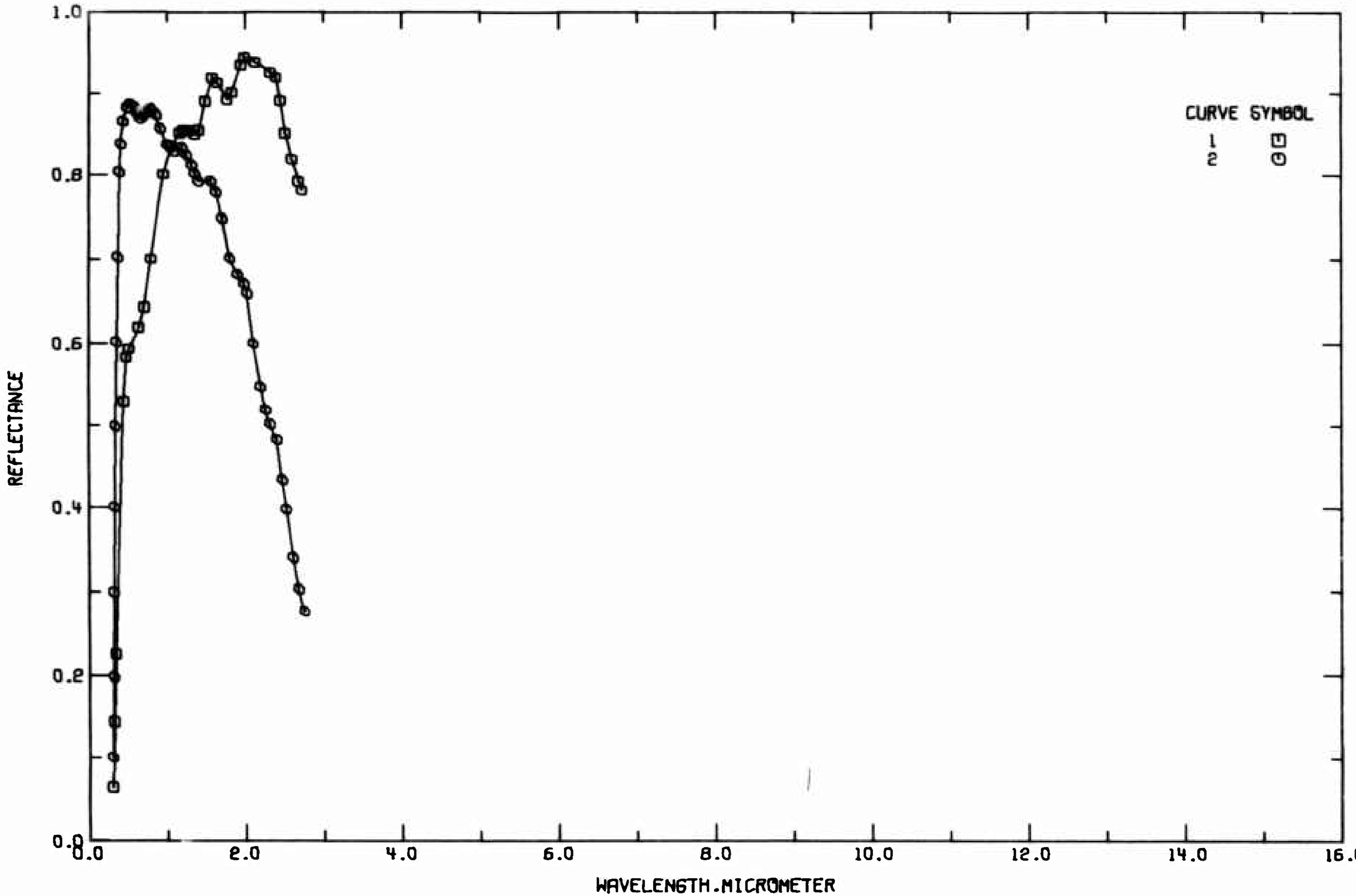


FIGURE 10-4. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF PYROCERAM (WAVELENGTH DEPENDENCE).

TABLE 10-6. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF PYROCERAM (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T10060	Olson, O.H. and Morris, J.C.	1959	0.30-2.7	293	Pyroceram 9606	Integrating sphere reflectometer used; reflectance factor measured then values converted to absolute reflectance values; working standard magnesium carbonate surface; smooth values from figure; temperature presumed to be room temperature, 293 K assigned; $\theta=9°$, $\omega'=2\pi$; reported error 4%.
2	T10060	Olson, O.H. and Morris, J.C.	1959	0.30-2.7	293	Pyroceram 9608	Integrating sphere reflectometer used; reflectance factor measured then values converted to absolute reflectance values; working standard magnesium carbonate surface; smooth values from figure; temperature presumed to be room temperature, 293 K assigned; $\theta=9°$, $\omega'=2\pi$; reported error 4%.

TABLE 10-7. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF PYROCERAM (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ
CURVE 1		CURVE 2(CONT.)	
T = 293.			
		0.338	0.499
0.297	0.062	0.355	0.601
0.318	0.142	0.372	0.702
0.339	0.224	0.391	0.803
0.446	0.529	0.407	0.839
0.480	0.552	0.440	0.865
0.516	0.593	0.493	0.882
0.639	0.619	0.534	0.887
0.710	0.642	0.603	0.882
0.795	0.700	0.623	0.875
0.952	0.800	0.652	0.870
1.05	0.835	0.696	0.873
1.16	0.852	0.755	0.878
1.21	0.854	0.792	0.881
1.28	0.854	0.861	0.874
1.35	0.850	0.915	0.858
1.41	0.855	1.001	0.838
1.49	0.889	1.085	0.829
1.58	0.918	1.139	0.834
1.64	0.912	1.246	0.825
1.77	0.891	1.312	0.812
1.83	0.900	1.352	0.801
1.94	0.934	1.397	0.792
1.99	0.944	1.557	0.792
2.12	0.938	1.625	0.779
2.32	0.925	1.700	0.746
2.39	0.919	1.798	0.701
2.45	0.890	1.960	0.681
2.51	0.852	1.981	0.670
2.59	0.819	2.017	0.659
2.68	0.791	2.099	0.600
2.72	0.780	2.191	0.547
		2.251	0.520
CURVE 2		2.309	0.502
T = 293.		2.392	0.483
		2.460	0.435
0.298	0.100	2.509	0.398
0.312	0.198	2.596	0.339
0.317	0.299	2.668	0.303
0.326	0.400	2.738	0.276

d. Hemispherical Spectral Transmittance (Wavelength Dependence)

There are four sets of experimental data for the wavelength dependence of the hemispherical spectral transmittance of Pyroceram with two data sets applicable to the specific material of interest here in this report, i.e., Corning 9606, and two data sets to a different Pyroceram, Corning 9608. The data for these four sets are listed in Table 10-9 and shown in Figure 10-5. Specimen characterization and measurement information for the data are given in Table 10-8.

The two sets of measurements of Folweiler [T29570] (curves 1 and 2) for Corning 9606 are both for room temperature. One set (curve 1) is for a specimen 0.005 inches thick and the second set (curve 2) is for a greater thickness of 0.016 in. As expected, the data for the greater thickness (curve 2) is less than the data for curve 1. The data for these two sets was given in tabular form and over widely spaced wavelengths. Because of this fact, no evaluated values are justified. It should further be pointed out that straight lines connecting the data points, as in Figure 10-5, are not meant to imply a smooth curve but are done that way for ease of visual presentation.

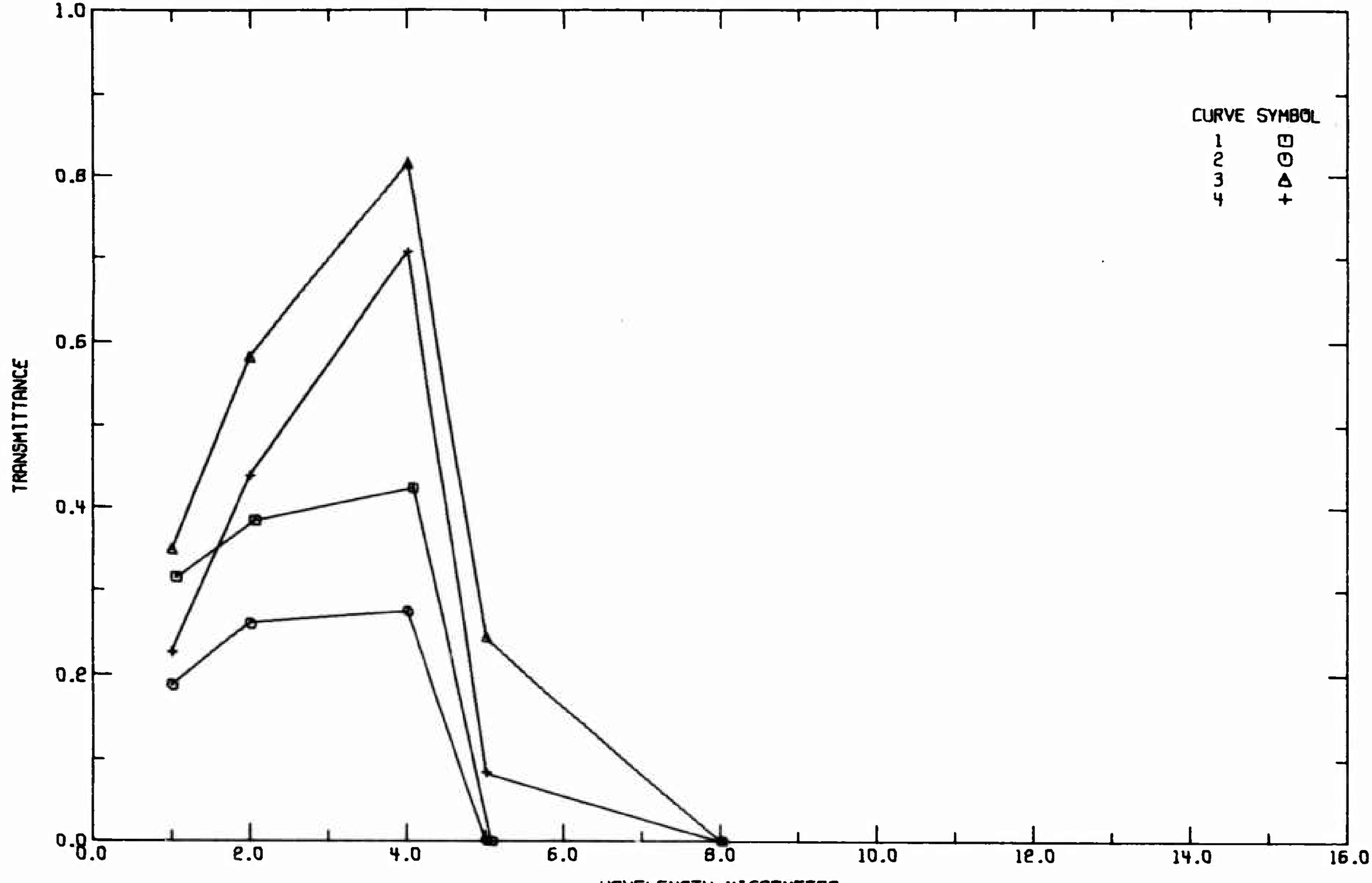


FIGURE 10-5. EXPERIMENTAL HEMISPHERICAL SPECTRAL TRANSMITTANCE OF PYROCERAM (WAVELENGTH DEPENDENCE).

TABLE 10-8. MEASUREMENT INFORMATION ON THE HEMISPHERICAL SPECTRAL TRANSMITTANCE OF PYROCERAM (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T29570	Folweiler, R.C.	1964	1-8	293	Corning 9606	Specimen 0.005 in. thick, cross-sectional dimensions 0.25 by 0.62 in., diffusing screen used in front of specimen; measurement temperature not given explicitly, assumed to be 293 K; $\theta'=0^{\circ}$, $\omega=2\pi$, reported error $\pm$ 5%.
2	T29570	Folweiler, R.C.	1964	1-8	293	Corning 9606	Similar to the above specimen except specimen is 0.010 in. thick.
3	T29570	Folweiler, R.C.	1964	1-8	293	Corning 9608	Specimen 0.008 in. thick, cross-sectional dimensions 0.25 by 0.62 in.; diffusing screen used in front of specimen; measurement temperature not given explicitly, assumed to be 293 K; $\theta'=0^{\circ}$, $\omega=2\pi$, reported error $\pm$ 5%.
4	T29570	Folweiler, R.C.	1964	1-8	293	Corning 9608	Similar to the above specimen except specimen is 0.016 in. thick.

TABLE 10-9. EXPERIMENTAL HEMISPHERICAL SPECTRAL TRANSMITTANCE OF PYROCERAM (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 1	
T = 293.	
1.	0.315
2.	0.385
4.	0.424
5.	0.0
8.	0.0
CURVE 2	
T = 293.	
1.	0.188
2.	0.259
4.	0.274
5.	0.0
8.	0.0
CURVE 3	
T = 293.	
1.	0.349
2.	0.532
4.	0.814
5.	0.243
8.	0.000
CURVE 4	
T = 293.	
1.	0.225
2.	0.435
4.	0.707
5.	0.084
8.	0.000

e. Normal Spectral Transmittance (Wavelength Dependence)

A total of 23 sets of experimental data were located for the wavelength dependence of the normal spectral transmittance of Pyroceram. These data sets are listed in Table 10-12 and shown in Figures 10-6 and 10-7. Specimen characterization and measurement information for the data are given in Table 10-11.

Of the 23 data sets only nine are specifically for Corning 9606 with data of eight reported by Folweiler [T29570] (curves 1-8) and data of the ninth reported by Hobbs and Folweiler [T39365], (curve 17). Data of curves 1 through 4 were given in tabular form and reported for integral wavelengths from 1 to 5 μm. On the other hand, data of curves 5-8 were given in graphical form and hence the shape of the curves is known. Curves 5-8 cover the wavelength range of 1 to 5 μm and data are reported for 293, 770, 900, and 1040 K. Data of curve 17 covers the wavelength region of 1 to 5 μm and is applicable to a temperature of 293 K.

Provisional values for 293 K and 1040 K are listed in Table 10-10 and shown in Figure 10-6 and apply to a specimen 3.18 mm thick. The values for 293 K are based on curve 5 while the values for 1040 K are based on curve 8. These values are called provisional because of the lack of much confirmatory evidence. The data of curve 17 is disregarded because the preponderance of evidence shows the transmittance reaching zero at 5 μm (curves 1 and 5 in Table 10-12 and Figure 10-7 together with curves 1 and 2 in Table 10-9 and Figure 10-5) whereas the data of curve 17 does not show this behavior. It is thought the uncertainty assigned to the two provisional curves is 20%.

TABLE 10-10. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF PYROCERAM(CORNING 9606) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ
3.18MM THICK		3.18MM THICK		3.18MM THICK		3.18MM THICK	
T = 293		T = 293 (CONT.)		T = 1040		T = 1040 (CONT.)	
1.00	0.681	3.15	0.227	1.00	0.600	3.50	0.219
1.10	0.703	3.20	0.236	1.10	0.630	3.60	0.219
1.08	0.700	3.21	0.239	1.14	0.650	3.70	0.219
1.20	0.723	3.30	0.269	1.20	0.656	3.80	0.219
1.30	0.742	3.37	0.300	1.39	0.677	3.90	0.219
1.33	0.748	3.40	0.314	1.40	0.696	4.00	0.219
1.40	0.761	3.48	0.350	1.42	0.700	4.10	0.216
1.50	0.775	3.50	0.360	1.50	0.714	4.11	0.216
1.53	0.779	3.58	0.400	1.60	0.732	4.20	0.210
1.60	0.788	3.60	0.420	1.68	0.743	4.30	0.202
1.70	0.800	3.67	0.443	1.70	0.746	4.33	0.200
1.80	0.807	3.70	0.454	1.80	0.754	4.40	0.193
1.82	0.809	3.74	0.467	1.84	0.757	4.42	0.191
1.88	0.811	3.80	0.485	1.90	0.760	4.50	0.177
1.90	0.812	3.86	0.500	1.94	0.761	4.60	0.159
2.00	0.813	3.90	0.507	2.00	0.757	4.62	0.154
2.09	0.807	3.92	0.511	2.10	0.747	4.67	0.139
2.10	0.806	4.00	0.513	2.16	0.740	4.70	0.134
2.20	0.796	4.10	0.514	2.20	0.730	4.73	0.125
2.21	0.794	4.19	0.500	2.30	0.704	4.78	0.100
2.23	0.778	4.20	0.499	2.31	0.700	4.80	0.094
2.30	0.774	4.30	0.481	2.40	0.656	4.86	0.080
2.39	0.759	4.39	0.457	2.44	0.641	4.90	0.064
2.40	0.744	4.40	0.452	2.50	0.600	4.91	0.060
2.43	0.734	4.46	0.423	2.55	0.546	4.96	0.040
2.50	0.703	4.50	0.408	2.60	0.510	4.98	0.026
2.54	0.682	4.52	0.400	2.61	0.530	5.00	0.000
2.60	0.638	4.60	0.355	2.66	0.444		
2.64	0.600	4.62	0.343	2.70	0.400		
2.70	0.538	4.69	0.300	2.80	0.300		
2.73	0.500	4.70	0.292	2.86	0.262		
2.80	0.400	4.77	0.241	2.90	0.244		
2.90	0.266	4.80	0.214	2.93	0.236		
2.86	0.300	4.82	0.206	3.00	0.222		
2.91	0.255	4.87	0.142	3.08	0.219		
2.95	0.238	4.90	0.116	3.10	0.219		
3.00	0.228	4.92	0.100	3.20	0.219		
3.07	0.223	4.96	0.045	3.30	0.219		
3.10	0.224	5.00	0.000	3.40	0.219		

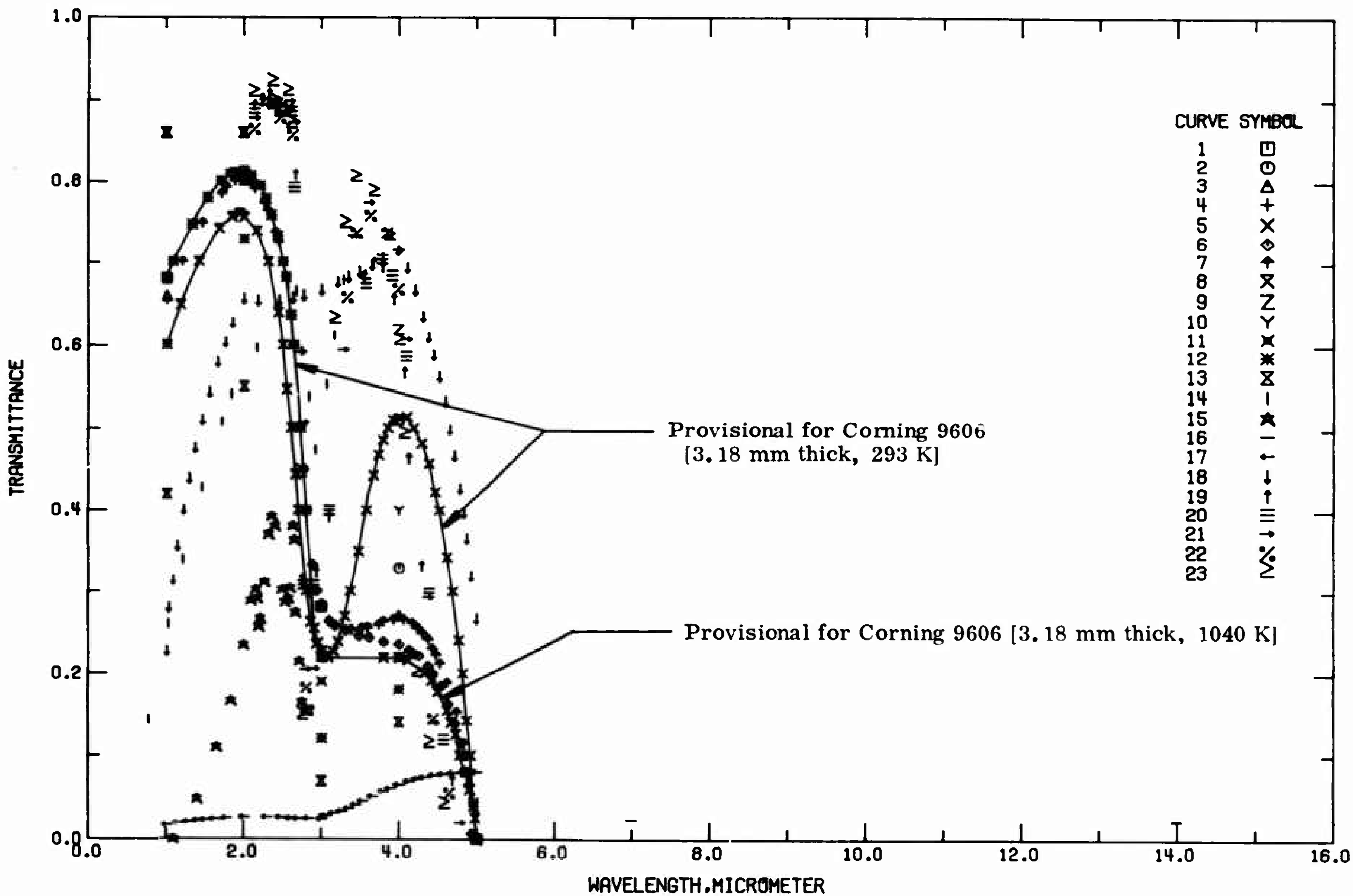


FIGURE 10-6. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF PYROCERAM (WAVELENGTH DEPENDENCE).

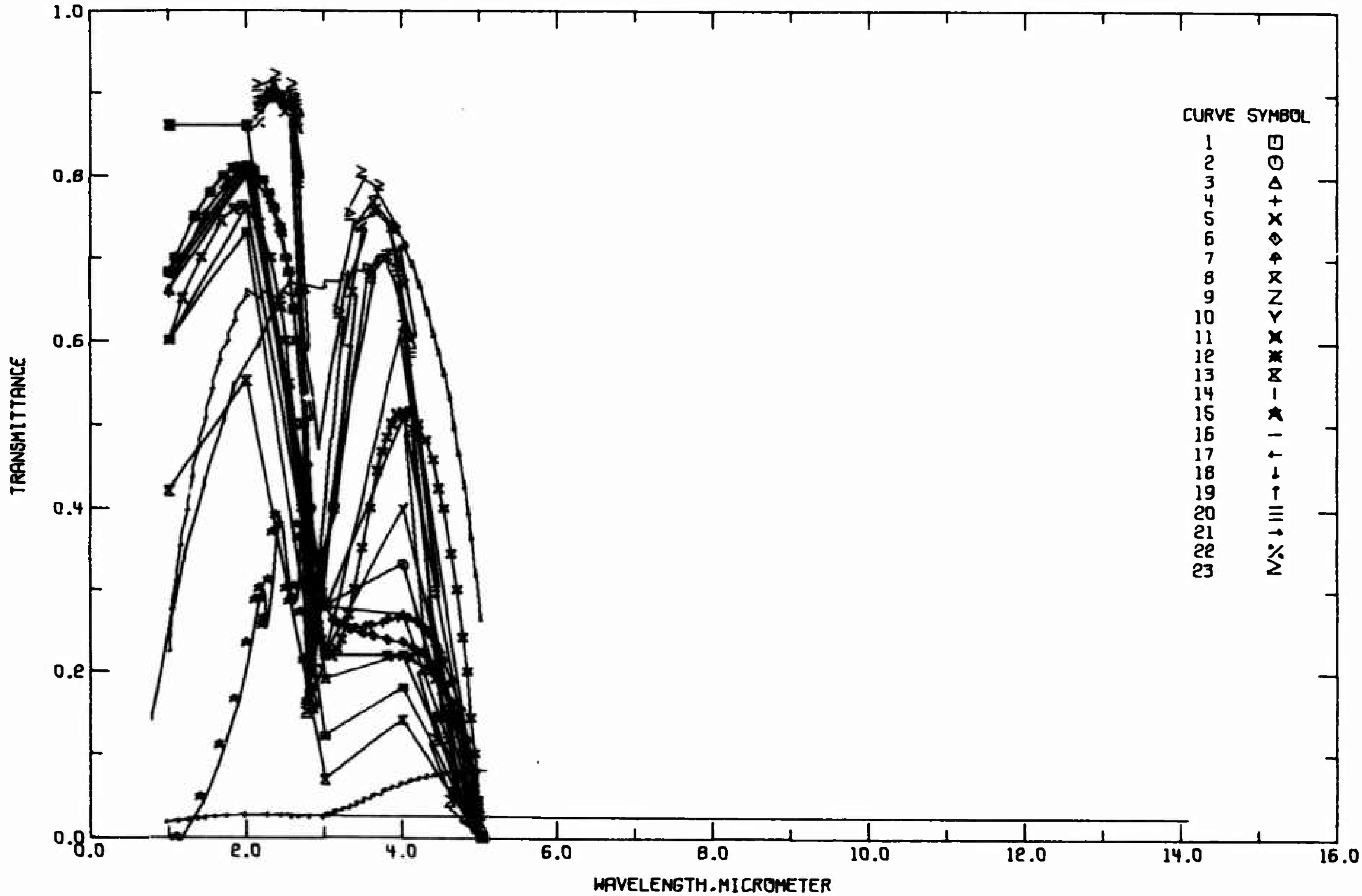


FIGURE 10-7. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF PYROCERAM (WAVELENGTH DEPENDENCE).

TABLE 10-11. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF PYROCERAM (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T29570	Folweiler, R.C.	1964	1-5	293	Pyroceram Glass 9606	Specimen dimensions 0.125 by 0.5 by 1.5 in.; $\theta=0°$, $\theta'=0°$; reported error ± 5%.
2	T29570	Folweiler, R.C.	1964	1-5	770	Pyroceram Glass 9606	The above specimen.
3	T29570	Folweiler, R.C.	1964	1-5	900	Pyroceram Glass 9606	The above specimen.
4	T29570	Folweiler, R.C.	1964	1-5	1040	Pyroceram Glass 9606	The above specimen.
5	T29570	Folweiler, R.C.	1964	1-5	293	Pyroceram Glass 9606	Similar to the above specimen except measurement temperature specified as room temperature, 293 K assigned, author reports transmissivity, uncorrected for surface reflectance, and data from figure.
6	T29570	Folweiler, R.C.	1964	1-5	770	Pyroceram Glass 9606	The above specimen.
7	T29570	Folweiler, R.C.	1964	1-5	900	Pyroceram Glass 9606	The above specimen.
8	T29570	Folweiler, R.C.	1964	1-5	1040	Pyroceram Glass 9606	The above specimen.
9	T29570	Folweiler, R.C.	1964	1-5	293	Corning 9608	Specimen dimensions 0.125 by 0.5 by 1.5 in.; uncorrected for surface reflectance; measurement temperature specified as room temperature, 293 K assigned; data from figure; $\theta=0°$, $\theta'=0°$; reported error ± 5%.
10	T29570	Folweiler, R.C.	1964	1-5	784	Corning 9608	The above specimen.
11	T29570	Folweiler, R.C.	1964	1-5	919	Corning 9608	The above specimen.
12	T29570	Folweiler, R.C.	1964	1-5	1070	Corning 9608	The above specimen.
13	T29570	Folweiler, R.C.	1964	1-5	1182	Corning 9608	The above specimen.
14	T31344	Kroeckel, O.	1964	0.77-3.3	293	Pyroceramic Material	Contains crystallites of about 0.5 μm diameter; little change in curve noted at 1173 K; smooth values from figure; reported error 3.5%.
15	T10060	Olson, O.H. and Morris, J.C.	1959	1.1-2.8	293	Pyroceram 9608	Integrating sphere reflectometer adopted for diffuse transmission measurements; smooth values from figure; $\theta=0°$, $\omega'=2\pi$.
16	T20771	Finkelstein, I.S.	1958	2-16	295	Pyroceram	Smooth values from figure; $\theta=0°$, $\theta'=0°$.
17	T39365	Hobbs, H.A. and Folweiler, R.C.	1966	1.0-5.0	293	Pyroceram 9606	Fully dense, no porosity; grain size optically indeterminate; thickness presumably 0.0152 cm (0.006 in.); author reports measured transmissivity; data from figure and smooth curve; $\theta=0°$, $\theta'=0°$, $\omega'=15/4\pi$.
18	T39365	Hobbs, H.A. and Folweiler, R.C.	1966	1.0-5.0	293	Pyroceram 9608	Fully dense, no porosity; grain size optically indeterminate; thickness presumably 0.0152 cm (0.006 in.); author reports measured transmissivity; data from figure and smooth curve; $\theta=0°$, $\theta'=0°$, $\omega'=15/4\pi$.
19	T[illegible]077	Troitskii, O.A. and Shmurak, S.Z.	19[illegible]5	2.1-5.0	293	Pyroceram	62 SiO_2, 29 Al_2O_3, 6.5 Li_2O, and additives containing TiO_2 as a catalyst; vitreous structure; specimen 1.5 mm thick and 25 x 25 cm; ground and polished to obtain plano-parallel sides; measurements made on a UR-10 spectrophotometer with a precision of ±10 cm^{-1}; smooth values from figure of infrared absorption spectra; measurement temperature not given explicitly, assumed to be 293 K; data taken to mean normal spectral transmittance; $\theta=0°$.

TABLE 10-11. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF PYROCERAM (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
20	T40977	Troitskii, O.A. and Shmurak, S.Z.	1966	2.1-5.0	293	Pyroceram	Similar to the above specimen except heated at 923 K for 10 hr.
21	T40977	Troitskii, O.A. and Shmurak, S.Z.	1966	2.1-5.0	293	Pyroceram	Similar to the above specimen except heated at 923 K for 10 hr and then heated at 1053 K for 0.5 hr; crystalline structure.
22	T40977	Troitskii, O.A. and Shmurak, S.Z.	1966	2.1-5.0	293	Pyroceram	Similar to the above specimen except heated at 923 K for 10 hr and then heated at 1053 K for 1 hr; crystalline structure.
23	T40977	Troitskii, O.A. and Shmurak, S.Z.	1966	2.1-5.0	293	Pyroceram	Similar to the above specimen except heated at 923 K for 10 hr and then heated at 1053 K for 7 hr; crystalline structure.

TABLE 13-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF PYROCERAM (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 1	
T = 293.	
1.	0.58
2.	0.31
3.	0.28
4.	0.51
5.	0.0
CURVE 2	
T = 770.	
1.	0.68
2.	0.31
3.	0.28
4.	0.33
5.	0.0
CURVE 3	
T = 900.	
1.	0.66
2.	0.80
3.	0.28
4.	0.27
5.	0.0
CURVE 4	
T = 1040.	
1.	0.60
2.	0.76
3.	0.22
4.	0.22
5.	0.0
CURVE 5	
T = 293.	
1.00	0.681
1.08	0.700
1.33	0.748
CURVE 5 (CONT.)	
1.53	0.779
1.70	0.800
1.82	0.809
1.88	0.811
2.00	0.813
2.09	0.807
2.21	0.794
2.28	0.778
2.35	0.759
2.43	0.734
2.50	0.700
2.54	0.682
2.60	0.638
2.64	0.600
2.73	0.500
2.80	0.400
2.86	0.300
2.91	0.255
2.95	0.238
3.00	0.228
3.07	0.223
3.15	0.227
3.21	0.239
3.30	0.269
3.37	0.300
3.48	0.350
3.58	0.400
3.67	0.443
3.74	0.467
3.80	0.485
3.86	0.500
3.92	0.511
4.00	0.513
4.10	0.514
4.19	0.500
4.30	0.481
4.39	0.457
4.46	0.423
4.52	0.400
4.62	0.343
CURVE 5 (CONT.)	
4.69	0.300
4.77	0.241
4.82	0.200
4.87	0.142
4.92	0.100
4.96	0.045
5.00	0.000
CURVE 6	
T = 770.	
1.00	0.681
1.08	0.700
1.33	0.748
1.53	0.779
1.70	0.800
1.82	0.809
1.88	0.811
2.00	0.813
2.09	0.807
2.21	0.794
2.28	0.778
2.35	0.759
2.43	0.734
2.50	0.700
2.54	0.682
2.60	0.638
2.64	0.600
2.73	0.500
2.77	0.450
2.81	0.400
2.88	0.334
2.94	0.300
3.00	0.283
3.10	0.263
3.17	0.258
3.31	0.252
3.48	0.246
3.61	0.244
3.80	0.239
CURVE 6 (CONT.)	
4.00	0.236
4.13	0.229
4.19	0.224
4.25	0.222
4.37	0.209
4.43	0.200
4.54	0.184
4.63	0.162
4.72	0.133
4.79	0.115
4.81	0.100
4.85	0.081
4.90	0.065
4.93	0.007
5.00	0.000
CURVE 7	
T = 900.	
1.00	0.656
1.20	0.700
1.46	0.750
1.71	0.784
1.77	0.792
1.83	0.800
1.94	0.804
2.00	0.801
2.09	0.795
2.14	0.790
2.26	0.774
2.30	0.765
2.40	0.739
2.44	0.726
2.50	0.700
2.54	0.682
2.60	0.638
2.64	0.600
2.73	0.500
2.77	0.450
2.81	0.400
CURVE 7 (CONT.)	
2.88	0.334
2.94	0.300
3.00	0.283
3.10	0.263
3.17	0.258
3.31	0.252
3.38	0.253
3.52	0.255
3.59	0.256
3.74	0.259
3.80	0.263
3.93	0.265
4.06	0.265
4.17	0.261
4.24	0.255
4.30	0.249
4.37	0.242
4.42	0.231
4.47	0.223
4.52	0.212
4.62	0.186
4.74	0.152
4.83	0.114
4.91	0.078
4.93	0.007
5.00	0.000
CURVE 8	
T = 1040.	
1.00	0.600
1.18	0.650
1.42	0.700
1.68	0.743
1.84	0.757
1.94	0.761
2.00	0.757
2.16	0.740
2.31	0.700
2.44	0.641
CURVE 8 (CONT.)	
2.50	0.600
2.55	0.546
2.61	0.500
2.66	0.444
2.70	0.400
2.80	0.300
2.86	0.262
2.93	0.236
3.00	0.222
3.08	0.219
3.80	0.219
4.00	0.219
4.11	0.216
4.33	0.200
4.42	0.191
4.50	0.177
4.62	0.154
4.67	0.139
4.73	0.125
4.78	0.100
4.86	0.080
4.91	0.060
4.96	0.040
4.98	0.026
5.00	0.000
CURVE 9	
T = 293.	
1.	0.86
2.	0.86
3.	0.22
4.	0.62
5.	0.0
CURVE 10	
T = 784.	
1.	0.86
2.	0.86

TABLE 10-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF PYROCERAM (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 10(CONT.)	
3.	0.22
4.	0.40
5.	0.0
CURVE 11	
T = 919.	
1.	0.36
2.	0.86
3.	0.19
4.	0.22
5.	0.0
CURVE 12	
T = 1070.	
1.	0.60
2.	0.73
3.	0.12
4.	0.18
5.	0.0
CURVE 13	
T = 1182.	
1.	0.42
2.	0.55
3.	0.37
4.	0.14
5.	0.5
CURVE 14	
T = 293.	
0.77	0.143
1.02	0.260
1.20	0.340
1.45	0.429
1.71	0.508
1.83	0.541

λ	τ
CURVE 14(CONT.)	
2.16	0.597
2.40	0.649
2.56	0.671
2.67	0.665
2.74	0.592
2.83	0.538
2.92	0.473
3.06	0.552
3.17	0.613
3.29	0.679
CURVE 15	
T = 293.	
1.08	0.000
1.39	0.049
1.54	0.110
1.83	0.166
1.99	0.235
2.09	0.288
2.15	0.302
2.17	0.290
2.19	0.257
2.21	0.266
2.26	0.312
2.32	0.370
2.36	0.392
2.40	0.380
2.49	0.302
2.53	0.286
2.57	0.290
2.59	0.304
2.63	0.383
2.65	0.363
2.67	0.273
2.71	0.215
2.75	0.164

λ	τ
CURVE 16	
T = 295.	
2.00	0.027
6.99	0.025
14.0	0.024
14.1	0.021
14.7	0.014
15.3	0.008
16.0	0.008
CURVE 17	
T = 293.	
1.00	0.0182
1.15	0.0200
1.28	0.0216
1.40	0.0228
1.50	0.0240
1.62	0.0251
1.77	0.0262
2.00	0.0273
2.29	0.0273
2.47	0.0268
2.60	0.0257
2.69	0.0253
2.83	0.0258
3.00	0.0249
3.05	0.0288
3.16	0.0319
3.26	0.0346
3.35	0.0379
3.44	0.0422
3.53	0.0467
3.66	0.0523
3.80	0.0580
3.89	0.0615
4.00	0.0659
4.13	0.0694
4.24	0.0722
4.33	0.0743
4.45	0.0767

λ	τ
CURVE 17(CONT.)	
4.57	0.0783
4.70	0.0797
4.84	0.0808
5.00	0.0807
CURVE 18	
T = 293.	
1.00	0.227
1.03	0.279
1.08	0.314
1.14	0.356
1.22	0.400
1.29	0.439
1.37	0.475
1.46	0.510
1.55	0.543
1.66	0.578
1.76	0.603
1.85	0.628
2.00	0.657
2.13	0.655
2.45	0.655
2.63	0.658
2.77	0.661
3.00	0.667
3.22	0.676
3.36	0.682
3.50	0.688
3.66	0.696
3.80	0.706
4.00	0.715
4.12	0.693
4.22	0.657
4.32	0.636
4.39	0.610
4.46	0.587
4.53	0.561
4.60	0.532
4.66	0.498

λ	τ
CURVE 18(CONT.)	
4.72	0.466
4.79	0.427
4.84	0.396
4.88	0.365
4.93	0.320
5.00	0.266
CURVE 19	
T = 293.	
2.14	0.892
2.24	0.897
2.33	0.907
2.46	0.892
2.59	0.884
2.66	0.839
2.75	0.316
2.82	0.295
2.93	0.325
3.10	0.391
3.56	0.683
3.68	0.699
3.80	0.694
3.94	0.657
4.08	0.566
4.13	0.463
4.29	0.333
4.44	0.188
4.69	0.071
5.00	0.000
CURVE 20	
T = 293.	
2.14	0.888
2.39	0.894
2.47	0.885
2.62	0.885
2.65	0.792
2.76	0.308

λ	τ
CURVE 20(CONT.)	
2.59	0.338
3.10	0.400
3.58	0.675
3.79	0.704
3.92	0.684
4.10	0.586
4.39	0.298
4.57	0.119
5.00	0.000
CURVE 21	
T = 293.	
2.14	0.877
2.27	0.893
2.42	0.900
2.49	0.882
2.59	0.836
2.65	0.872
2.73	0.591
2.76	0.507
2.79	0.205
2.84	0.157
2.90	0.206
3.28	0.594
3.42	0.735
3.62	0.774
4.00	0.716
4.10	0.635
4.37	0.292
4.44	0.139
4.78	0.021
5.00	0.000
CURVE 22	
T = 293.	
2.14	0.864
2.29	0.901
2.38	0.894

TABLE 10-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF PYROCERAM (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 22 (CONT.)	
2.47	0.877
2.58	0.890
2.63	0.857
2.75	0.399
2.80	0.162
2.82	0.154
3.34	0.659
3.46	0.738
3.64	0.759
3.85	0.738
4.00	0.668
4.44	0.144
4.65	0.056
5.00	0.000
CURVE 23	
T = 293.	
2.14	0.907
2.38	0.920
2.43	0.895
2.58	0.908
2.62	0.869
2.73	0.445
2.76	0.146
2.80	0.152
3.18	0.632
3.32	0.748
3.46	0.803
3.69	0.785
3.89	0.733
4.02	0.604
4.08	0.491
4.24	0.200
4.39	0.113
4.59	0.041
5.00	0.000

f. Normal Spectral Transmittance (Temperature Dependence)

No experimental data sets specifically for the temperature dependence of the normal spectral transmittance of Corning 9606 were found. However, from curves 5, 6, 7, and 8 of the previous section (see Tables 10-11 and 10-12), the transmittance value at 3.80 μm is 0.485, 0.239, 0.263, and 0.219 at 293 K, 770 K, 900 K, and 1040 K, respectively.

4.11. Silica(Vitreous)

This material is labeled "Silica(Vitreous)" in the above heading so that in alphabetization this material will fall under "s". However, in this discussion the wording "vitreous silica" will be used for ease in reading.

Vitreous silica is a glass which is composed essentially of SiO_2. The most general and unambiguous term that refers to the entire range of noncrystalline silica is vitreous silica. It is also known as fused silica, silica glass, and fused quartz. Additional information is available concerning the terminology and naming [T76945, T76946, A00026]. The two general types of vitreous silica are transparent and nontransparent. The latter arises from microscopic bubbles in the material. The emphasis in this section is to give evaluated data for the transparent type of vitreous silica.

Vitreous silica has many interesting physical properties. One source [T34753] gives a range for the melting point of 1950 to 2000 K while another source [A00017] identifies the melting point as 1996 K. It boils at 2500 K. The density is about 2.2 g cm^{-3}. One distinction for vitreous silica is that the coefficient of thermal expansion is among the lowest of all known materials. In the range of 273-573 K, the range for the linear expansion coefficient is between 5.4 and 5.6 x 10^{-7} C^{-1}. At approximately 293 K, Young's modulus is 730 kbar, the shear modulus 311 kbar, and Poisson's ratio 0.17. The Knoop hardness falls in the range of 545-575 kg mm^{-2}.

a. Normal Spectral Emittance (Wavelength Dependence)

A total of six sets of experimental data were located for the wavelength dependence of the normal spectral emittance of vitreous silica. The data are listed in Table 11-3 and shown in Figures 11-1 and 11-2. Specimen characterization and measurement information for the data are given in Table 11-2.

Stierwalt [T16961] (curve 1) reported data for a specimen 0.84 mm thick at a temperature of 313 K. Dumbaugh and Schultz [T76945] reported calculations of Parker for a 0.50 in. thick specimen at room temperature (curve 2) and also for a 0.250 in. thick specimen (curve 3). Champetier and Friese [A00012] reported data for Optosil 1 at a temperature of 373 K for parallel polarization of the light emitted (curve 4), for perpendicular polarization (curve 5), and for unpolarized light (curve 6).

Above 5 μm, all the data show the same general trend. From 5 to 6 μm the emittance is greater than 0.9. From that region the values fall, in the wavelength range of 8 to 9 μm, to a minimum. From the minimum, the values rise and above 11 μm the

values are greater than 0.85. In addition, above 5 μm the data of curves 1 and 2 are close together. The value of the wavelength at which the minimum occurs for two groups of data is different. For curves 5 and 6 (Honeywell data), the wavelength at which the minimum occurs is 8.3 μm while for curves 1 and 2 it is 8.9 μm.

Calculations were carried out to determine the emittance for radiation that is polarized perpendicular to the plane of incidence (curves 7-9), the emittance for radiation that is polarized parallel to the plane of incidence (curves 10-12), and the emittance for unpolarized radiation (curves 13-15). The calculation for emittance with radiation polarized perpendicular to the plane of incidence was carried out in the following sequence: First the Fresnel equation for specular reflection for radiation polarized perpendicular to the plane of incidence was used, Eq. (2.4-1). Kirchhoff's law was then applied and Eq. (2.4-6) used to determine the emittance for radiation polarized perpendicular to the plane of incidence. The appropriate equations were used for radiation polarized parallel to the plane of incidence (see Eqs. (2.4-2) and (2.4-7)) and for unpolarized radiation (see Eqs. (2.4-5) and (2.4-8)).

The calculations of the emittance, or absorptance, using Eqs. (2.4-6) through (2.4-8) are based on the fact the material is opaque, i.e., the transmittance is zero. Champetier and Friese [A00012] reported transmittance for a 1 mm thick specimen of Optosil 1 at 293 K from 3.7 to 16 μm and found it to be opaque (see curve 38, Table 11-23). Hence, direct evidence exists for opaqueness to 16 μm and, therefore, calculations were not carried out past 16 μm.

The Fresnel equations are functions of the index of refraction n and the absorption index k as well as the angle of incidence θ. The index of refraction of vitreous silica is shown in Figure 11-3 and listed in Table 11-5. Specimen characterization and measurement information for the data of the index of refraction are given in Table 11-4. The absorption index of vitreous silica is shown in Figure 11-4 and listed in Table 11-7. Specimen characterization and measurement information for the data of absorption index are given in Table 11-6. Table 11-5 lists four places below the decimal point for wavelength values and five places below the decimal point for index of refraction values. If original data was given to more decimal places, the computer program generating Table 11-5 truncated and dropped the additional digits. The original data of curve 2 was given for up to five places below the decimal point for wavelength values and the original data for wavelength values of curves 1, 3-7, and 12 was given for up to six places below the decimal point. The original data for index of refraction of curves 3-7 was given for six places below the decimal point. The index of refraction and the absorption index values

used in the calculations were taken from Champetier and Friese [A00012, p. 61]. The index of refraction from Champetier and Friese is curve 11 in Figure 11-3 and in Tables 11-4 and 11-5; the absorption index is curve 3 in Figure 11-4 and Tables 11-6 and 11-7. The Champetier and Friese data is for a wavelength range of 7 to 26 μm, a temperature of 293 K, and is based on data in the literature. Below 9 μm it is based on the data of Zolotorev [T60820] and above 9 μm it is based on the data of Popova, Tolstykh, and Vorobev [E64849].

The calculations using the Fresnel equations were programmed and carried out for all wavelengths from 7 to 16 μm for which refractive index and absorption index data were given by Champetier and Friese. The calculations are valid for an optically smooth surface of vitreous silica, a temperature of 293 K, and a wavelength range of 7 to 16 μm. The lower range of the calculations were 7 μm since the data of the index of refraction and absorption index needed in the Fresnel equations only started at 7 μm. Optically smooth means the surface is "smooth in comparison with the wavelength of the incident radiation so that specular reflections result" [p. 111, T52053].

Because of the comment made in [A00012] questioning the validity of the data reported as curves 4, 5, and 6, this data was disregarded in developing evaluated values. A set of provisional values for vitreous silica at 293 K is listed in Table 11-1 and shown in Figure 11-1. Below 7 μm the provisional values are based on curve 2 and, therefore, apply to a 0.50 in. thick specimen of Corning 7940 vitreous silica. From 7 to 16 μm, the provisional values were calculated for unpolarized radiation. The calculated provisional values hold for an optically smooth specimen at 293 K that is opaque and has a viewing angle of 0°.

Because of the index of refraction and absorption index data are not themselves fully evaluated, the calculated emittance is called provisional. Below 7 μm the values for Corning 7940 do not have supporting evidence and it is only justified in labeling them provisional. Another reason for calling the calculated values above 7 μm provisional is that these values are close to curve 2 but do differ. An uncertainty of within 30% is therefore assigned to the provisional values. The provisional value at 10.6 μm of the normal spectral emittance at 293 K is 0.89. It is noted that high temperature normal spectral emittance data was not located.

TABLE 11-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε	λ	ε
CORNING 7940 1.27CM THICK T = 293		CORNING 7940 1.27CM THICK T = 293 (CONT.)		OPTICALLY SMOOTH T = 293		OPTICALLY SMOOTH T = 293 (CONT.)	
2.14	0.026	4.49	0.970	7.00	0.999	10.4	0.855
2.32	0.042	4.55	0.976	7.10	1.000	10.6	0.887
2.42	0.062	4.66	0.974	7.20	1.000	10.8	0.889
2.50	0.083	4.81	0.973	7.30	1.000	11.0	0.897
2.52	0.131	4.99	0.973	7.40	1.000	11.2	0.902
2.52	0.252	5.00	0.974	7.50	0.999	11.4	0.909
2.50	0.408	5.27	0.979	7.60	0.997	11.6	0.915
2.51	0.439	5.56	0.986	7.70	0.990	11.8	0.923
2.54	0.473	5.77	0.986	7.80	0.980	12.0	0.923
2.58	0.568	5.88	0.986	7.90	0.949	12.2	0.917
2.58	0.643	6.00	0.986	8.00	0.865	12.4	0.907
2.58	0.682	6.18	0.989	8.10	0.732	12.6	0.894
2.58	0.762	6.40	0.993	8.20	0.686	12.8	0.881
2.63	0.914	6.62	0.994	8.30	0.694	13.0	0.890
2.62	0.957	6.78	0.993	8.40	0.664	13.2	0.898
2.68	0.970	6.90	0.993	8.50	0.632	13.4	0.903
2.76	0.957			8.60	0.578	13.6	0.911
2.81	0.888			8.65	0.539	13.8	0.919
2.81	0.687			8.70	0.479	14.0	0.923
2.85	0.623			8.75	0.433	14.2	0.928
2.95	0.524			8.80	0.368	14.4	0.857
3.00	0.450			8.85	0.321	14.6	0.935
3.03	0.395			8.90	0.298	16.0	0.960
3.03	0.313			8.95	0.281		
3.09	0.299			9.00	0.330		
3.22	0.302			9.05	0.382		
3.39	0.315			9.10	0.535		
3.50	0.332			9.15	0.470		
3.57	0.410			9.20	0.526		
3.61	0.471			9.30	0.547		
3.67	0.547			9.35	0.584		
3.74	0.642			9.40	0.689		
3.80	0.699			9.50	0.657		
3.88	0.803			9.60	0.687		
3.95	0.890			9.70	0.716		
4.00	0.907			9.80	0.748		
4.05	0.927			9.90	0.771		
4.21	0.952			10.0	0.795		
4.37	0.965			10.2	0.834		

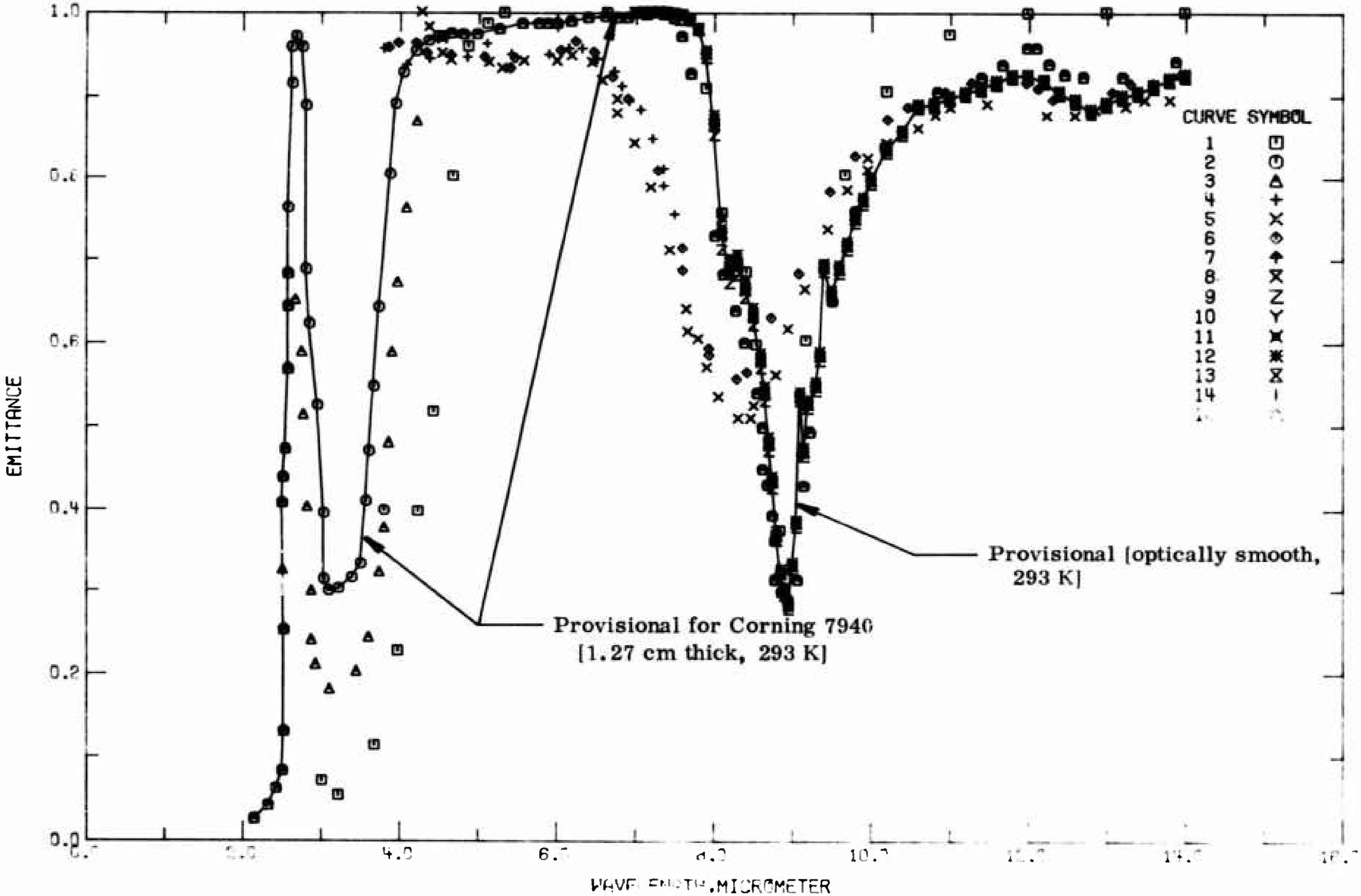


FIGURE 11-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF SILICA (VITREOUS) (WAVELENGTH DEPENDENCE).

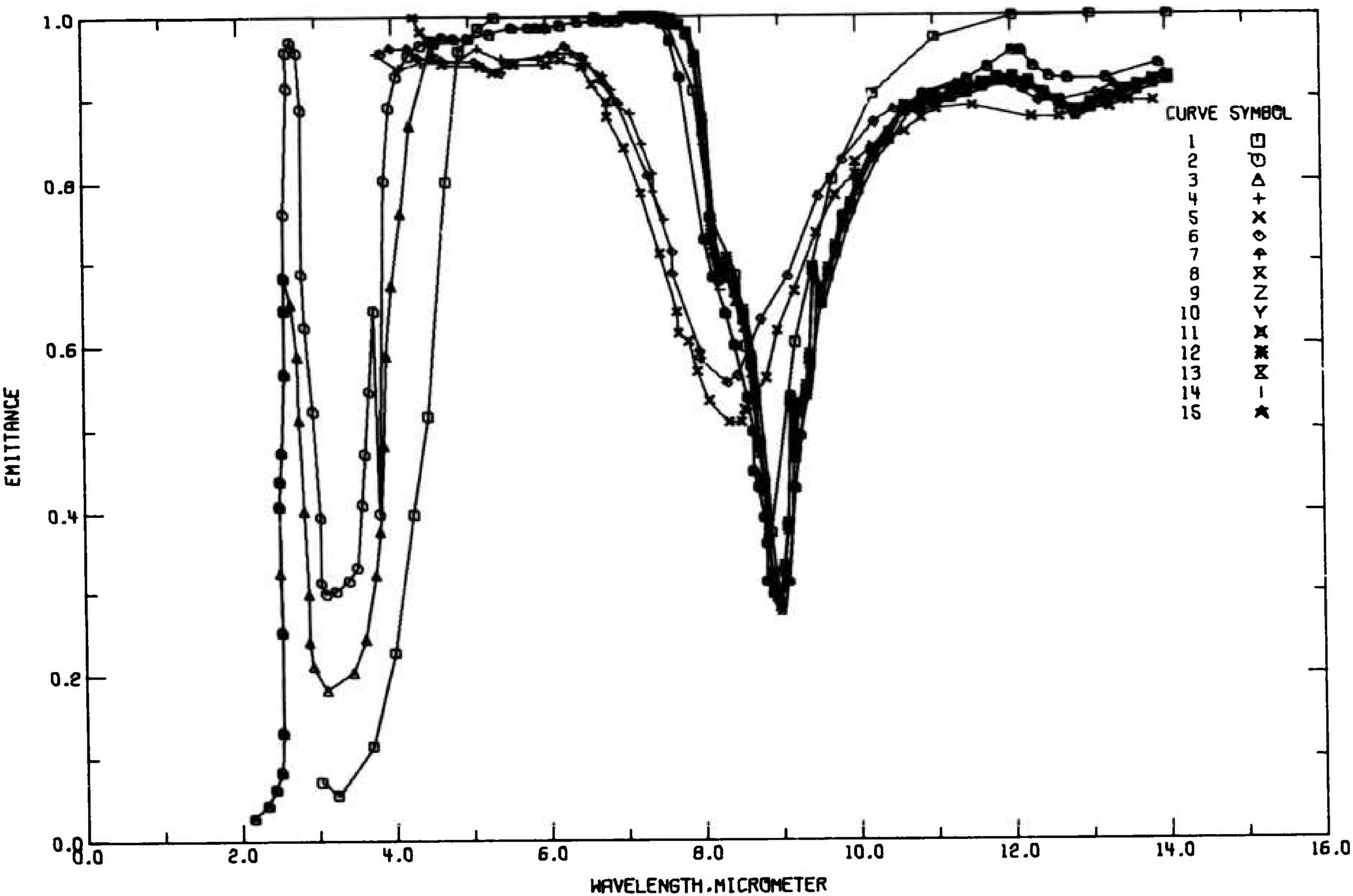


FIGURE 11-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

TABLE 11-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF SILICA(VITREOUS) (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T16961	Stierwalt, D. L.	1961	3.0-14	313	Fused quartz	Plate 0.84 mm thick; measured in vacuum; smooth values from figure; spectral emissivity reported; $\theta' \sim 0^\circ$.
2	T76945	Dumbaugh, W.H. and Schultz, P.C.	1969	2.1-25	293	Corning Code 7940 vitreous silica	Specimen 0.50 in. thick; emissivity calculated by C. J. Parker from room temperature (293 K assigned) measurements of transmittance and reflectance.
3	T76945	Dumbaugh, W.H. and Schultz, P.C.	1969	2.1-25	293	Corning Code 7940 vitreous silica	Similar to the above specimen except specimen 0.250 in. thick.
4	A00012	Champetier, R.J. and Friese, G.J.	1974	3.8-7.5	373	Optosil 1	Specimen thickness 0.125 in.; polished disk; Honeywell spectral emissometer used which includes a Leiss double prism monochromator with prisms of potassium or cesium bromide; computed system band width 0.19 μm; optics, chopper, and enclosure near 300 K while sample and black body reference are heated to 373 K; polarization of monochromator which is present has not been removed from data; 0° data taken but not reported, the 0° and 12° data were identical; emittance data for parallel polarization; a conclusion in this report [A00012] is that "Honeywell emissometer currently produces incorrect data at angles greater than 40 degrees and previously generated data cannot be used with confidence in their validity."; smooth values from figure; because of overlap of curves, data could not be extracted for full wavelength range for which data reported; $\theta' = 12^\circ$.
5	A00012	Champetier, R.J. and Friese, G.J.	1974	4.3-24	373	Optosil 1	Similar to the above specimen except for perpendicular polarization.
6	A00012	Champetier, R.J. and Friese, G.J.	1974	3.9-20	373	Optosil 1	Similar to the above specimen except for unpolarized light.
7	A00012		1975	7.0-16	293		Calculations for fused silica performed for a homogeneous, smooth surface and for perpendicular component of radiation, equations (2.4-6), (2.4-1), (2.4-3), and (2.4-4); data for index of refraction, n, and absorption index, k, from [A00012]; $\theta' = 0^\circ$.
8	A00012		1975	7.0-16	293		Similar to the above specimen except $\theta' = 5^\circ$.
9	A00012		1975	7.0-16	293		Similar to the above specimen except $\theta' = 10^\circ$.
10	A00012		1975	7.0-16	293		Similar to the above specimen except for parallel component of radiation, equation (2.4-7) and $\theta' = 0^\circ$.
11	A00012		1975	7.0-16	293		Similar to the above specimen except $\theta' = 5^\circ$.
12	A00012		1975	7.0-16	293		Similar to the above specimen except $\theta' = 10^\circ$.
13	A00012		1975	7.0-16	293		Similar to the above specimen except for unpolarized radiation, equation (2.4-8), and $\theta' = 0^\circ$.
14	A00012		1975	7.0-16	293		Similar to the above specimen except $\theta' = 5^\circ$.
15	A00012		1975	7.0-16	293		Similar to the above specimen except $\theta' = 10^\circ$.

TABLE 11-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE 1		CURVE	2(CONT.)	CURVE	2(CONT.)	CURVE	2(CONT.)	CURVE	3(CONT.)	CURVE	3(CONT.)
T = 313.											
		2.58	0.682	6.90	0.997	16.77	0.982	2.54	0.473	8.01	0.728
3.00	0.071	2.58	0.762	7.14	0.997	17.24	0.987	2.58	0.568	8.12	0.681
3.21	0.054	2.63	0.914	7.36	0.997	17.55	0.985	2.58	0.643	8.28	0.638
3.67	0.114	2.62	0.957	7.49	0.992	18.37	0.985	2.58	0.682	8.39	0.600
3.97	0.227	2.68	0.970	7.59	0.970	18.66	0.990	2.67	0.651	8.55	0.539
4.23	0.398	2.76	0.957	7.71	0.926	18.89	0.997	2.75	0.589	8.62	0.498
4.43	0.517	2.81	0.885	8.01	0.728	19.14	0.988	2.77	0.513	8.62	0.449
4.68	0.801	2.81	0.687	8.12	0.681	19.29	0.965	2.82	0.403	8.68	0.430
4.87	0.958	2.85	0.623	8.28	0.638	19.47	0.937	2.87	0.299	8.75	0.393
5.12	0.986	2.95	0.524	8.39	0.600	19.55	0.905	2.87	0.240	8.78	0.361
5.33	0.999	3.03	0.395	8.55	0.539	19.63	0.870	2.92	0.211	8.78	0.313
6.64	0.999	3.03	0.313	8.62	0.498	19.76	0.825	3.10	0.182	8.86	0.298
7.56	0.990	3.09	0.299	8.62	0.449	19.92	0.738	3.44	0.203	8.94	0.289
7.90	0.909	3.22	0.302	8.68	0.430	20.48	0.485	3.60	0.243	9.06	0.313
8.10	0.756	3.39	0.315	8.75	0.393	20.55	0.467	3.74	0.322	9.15	0.429
8.41	0.684	3.50	0.332	8.78	0.361	20.66	0.451	3.80	0.377	9.23	0.493
8.54	0.598	3.57	0.410	8.78	0.313	20.80	0.444	3.86	0.481	9.51	0.649
8.84	0.374	3.61	0.471	8.86	0.298	21.00	0.453	3.90	0.589	9.80	0.758
9.17	0.603	3.67	0.547	8.94	0.289	21.16	0.486	3.97	0.672	10.18	0.838
9.67	0.803	3.74	0.642	9.06	0.313	21.74	0.586	4.09	0.762	10.60	0.886
10.2	0.905	3.80	0.399	9.15	0.429	21.99	0.623	4.22	0.869	10.85	0.904
11.0	0.973	3.88	0.803	9.23	0.493	22.39	0.670	4.53	0.970	11.41	0.921
12.0	0.999	3.95	0.890	9.51	0.649	22.79	0.704	4.66	0.974	11.68	0.936
13.0	1.00	4.05	0.927	9.80	0.758	23.21	0.728	4.81	0.973	11.99	0.956
14.0	1.00	4.21	0.952	10.18	0.838	23.74	0.751	4.99	0.973	12.11	0.956
		4.37	0.965	10.60	0.886	24.35	0.775	5.27	0.979	12.27	0.937
CURVE 2		4.49	0.970	10.85	0.904	24.91	0.801	5.56	0.986	12.47	0.925
T = 293.		4.55	0.970	11.41	0.921			5.77	0.986	12.71	0.922
		4.66	0.974	11.68	0.936	CURVE 3		5.88	0.986	13.21	0.922
2.14	0.026	4.81	0.973	11.99	0.956	T = 293.		6.00	0.986	13.89	0.940
2.32	0.042	4.99	0.973	12.11	0.956			6.18	0.989	14.61	0.961
2.42	0.062	5.27	0.979	12.27	0.937	2.14	0.026	6.40	0.993	15.59	0.974
2.50	0.083	5.56	0.986	12.47	0.925	2.32	0.042	6.62	0.994	16.00	0.977
2.52	0.131	5.77	0.986	12.71	0.922	2.42	0.062	6.78	0.993	16.49	0.977
2.52	0.252	5.88	0.986	13.21	0.922	2.50	0.083	6.90	0.993	16.77	0.982
2.50	0.408	6.00	0.986	13.89	0.940	2.52	0.131	7.14	0.997	17.24	0.987
2.51	0.439	6.18	0.989	14.61	0.961	2.52	0.252	7.36	0.997	17.55	0.985
2.54	0.473	6.40	0.993	15.59	0.974	2.50	0.325	7.49	0.992	18.37	0.985
2.58	0.568	6.62	0.994	16.00	0.977	2.50	0.408	7.59	0.970	18.66	0.990
2.58	0.643	6.78	0.993	16.49	0.977	2.51	0.439	7.71	0.926	18.89	0.997

TABLE 11-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE	3(CONT.)
19.14	0.988
19.29	0.965
19.47	0.937
19.55	0.905
19.63	0.870
19.76	0.825
19.92	0.738
20.48	0.485
20.55	0.467
20.66	0.451
20.80	0.444
21.00	0.453
21.16	0.486
21.74	0.586
21.99	0.623
22.38	0.670
22.79	0.704
23.21	0.728
23.74	0.751
24.35	0.775
24.91	0.801
CURVE 4	
T = 373.	
3.80	0.955
4.09	0.936
4.38	0.943
4.86	0.945
5.11	0.961
5.42	0.948
5.90	0.948
6.15	0.955
6.32	0.955
6.51	0.943
6.73	0.929
6.83	0.911
6.92	0.893
7.07	0.883
7.22	0.847

λ	ε
CURVE	4(CONT.)
7.36	0.810
7.36	0.789
7.50	0.754
CURVE 5	
T = 373.	
4.28	1.000
4.37	0.982
4.54	0.967
4.54	0.950
4.65	0.942
5.14	0.939
5.30	0.932
5.58	0.941
6.00	0.941
6.19	0.947
6.45	0.939
6.58	0.918
6.77	0.896
6.77	0.879
6.99	0.642
7.20	0.787
7.44	0.711
7.65	0.640
7.67	0.614
7.80	0.605
7.91	0.570
8.06	0.535
8.31	0.509
8.47	0.509
8.51	0.524
8.79	0.561
8.94	0.617
9.16	0.664
9.45	0.736
9.70	0.784
9.96	0.809
9.96	0.824
10.20	0.842

λ	ε
CURVE	5(CONT.)
10.60	0.850
10.82	0.876
11.01	0.886
11.48	0.890
12.24	0.876
12.60	0.876
12.86	0.883
13.25	0.887
13.49	0.895
13.81	0.895
14.36	0.903
14.58	0.916
14.85	0.926
15.31	0.923
15.60	0.928
15.72	0.922
15.91	0.930
16.37	0.928
16.54	0.932
16.91	0.932
17.10	0.936
17.27	0.942
17.43	0.935
18.06	0.937
18.14	0.950
18.35	0.956
18.57	0.944
18.74	0.944
18.86	0.951
19.03	0.945
19.29	0.945
19.69	0.904
19.83	0.869
20.15	0.748
20.39	0.666
20.66	0.540
20.87	0.475
21.13	0.436
21.32	0.418
21.45	0.421

λ	ε
CURVE	5(CONT.)
21.71	0.477
21.83	0.489
21.99	0.530
22.35	0.534
22.53	0.585
22.60	0.593
22.76	0.593
22.88	0.604
22.88	0.615
23.00	0.623
23.15	0.656
23.28	0.661
23.28	0.668
23.44	0.575
23.51	0.659
23.65	0.682
23.79	0.678
23.93	0.668
24.00	0.689
CURVE 6	
T = 373.	
3.86	0.956
3.98	0.962
4.21	0.962
4.34	0.959
4.65	0.947
5.08	0.945
5.41	0.932
5.46	0.944
6.05	0.953
6.24	0.964
6.47	0.951
6.71	0.922
6.91	0.896
7.29	0.809
7.60	0.713
7.60	0.686
7.94	0.593

λ	ε
CURVE	6(CONT.)
7.94	0.585
8.29	0.556
8.42	0.564
8.73	0.630
9.08	0.682
9.48	0.782
9.80	0.826
10.21	0.871
10.47	0.886
10.60	0.889
10.95	0.904
11.28	0.915
11.98	0.915
12.13	0.908
12.32	0.895
12.61	0.895
13.08	0.904
13.31	0.914
13.60	0.914
13.94	0.924
14.10	0.916
14.28	0.920
14.44	0.932
14.58	0.926
14.76	0.935
14.95	0.931
15.49	0.947
15.67	0.942
16.85	0.955
17.06	0.948
17.37	0.954
17.69	0.954
18.30	0.960
18.50	0.967
18.85	0.967
18.99	0.962
19.20	0.940
19.58	0.931
19.80	0.888
19.82	0.871

λ	ε
CURVE	6(CONT.)
20.00	0.856
CURVE 7	
T = 293.	
7.00	0.99940
7.10	0.99960
7.20	0.9999
7.30	0.9999
7.40	0.9995
7.50	0.9985
7.60	0.9969
7.70	0.9904
7.80	0.9796
7.90	0.9489
8.00	0.8649
8.10	0.7319
8.20	0.6863
8.30	0.6936
8.40	0.6640
8.50	0.6318
8.60	0.5784
8.65	0.5387
8.70	0.4793
8.75	0.4334
8.80	0.3675
8.85	0.3206
8.90	0.2982
8.95	0.2813
9.00	0.3296
9.05	0.3824
9.10	0.5351
9.15	0.4699
9.20	0.5256
9.30	0.5473
9.35	0.5836
9.40	0.6894
9.50	0.6567
9.60	0.6871
9.70	0.7159

TABLE 11-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ)

λ	ϵ
CURVE 7(CONT.)	
9.80	0.7479
9.90	0.7705
10.0	0.7950
10.2	0.8335
10.4	0.8548
10.6	0.8874
10.8	0.8886
11.0	0.8971
11.2	0.9023
11.4	0.9085
11.6	0.9152
11.8	0.9225
12.0	0.9229
12.2	0.9172
12.4	0.9034
12.6	0.8937
12.8	0.8814
13.0	0.8899
13.2	0.8982
13.4	0.9030
13.6	0.9113
13.8	0.9190
14.0	0.9234
14.2	0.9277
14.4	0.8567
14.6	0.9348
16.0	0.9602
CURVE 8 T = 293.	
7.00	0.9994
7.10	0.9996
7.20	0.9998
7.30	0.9999
7.40	0.9995
7.50	0.9985
7.60	0.9968
7.70	0.9923
7.80	0.9792

λ	ϵ
CURVE 8(CONT.)	
7.90	0.9477
8.00	0.8615
8.10	0.7268
8.20	0.6824
8.30	0.6902
8.40	0.6611
8.50	0.6291
8.60	0.5760
8.65	0.5363
8.70	0.4772
8.75	0.4315
8.80	0.3659
8.85	0.3192
8.90	0.2969
8.95	0.2802
9.00	0.3284
9.05	0.3812
9.10	0.5336
9.15	0.4686
9.20	0.5242
9.30	0.5459
9.35	0.5822
9.40	0.6880
9.50	0.6553
9.60	0.6858
9.70	0.7146
9.80	0.7466
9.90	0.7632
10.0	0.7938
10.2	0.8324
10.4	0.8538
10.6	0.8866
10.8	0.8878
11.0	0.8963
11.2	0.9015
11.4	0.9077
11.6	0.9145
11.8	0.9218
12.0	0.9222
12.2	0.9165

λ	ϵ
CURVE 8(CONT.)	
12.4	0.9026
12.6	0.8928
12.8	0.8805
13.0	0.8891
13.2	0.8974
13.4	0.9023
13.6	0.9105
13.8	0.9183
14.0	0.9227
14.2	0.9271
14.4	0.8557
14.6	0.9342
16.0	0.9598
CURVE 9 T = 293.	
7.00	0.9993
7.10	0.9995
7.20	0.9998
7.30	0.9999
7.40	0.9995
7.50	0.9984
7.60	0.9966
7.70	0.9897
7.80	0.9773
7.90	0.9439
8.00	0.8510
8.10	0.7112
8.20	0.6705
8.30	0.6800
8.40	0.6527
8.50	0.6212
8.60	0.5686
8.65	0.5295
8.70	0.4710
8.75	0.4259
8.80	0.3610
8.85	0.3150
8.90	0.2931

λ	ϵ
CURVE 9(CONT.)	
8.95	0.2769
9.00	0.3249
9.05	0.3775
9.10	0.4293
9.15	0.4645
9.20	0.5200
9.30	0.5416
9.35	0.5779
9.40	0.6838
9.50	0.6511
9.60	0.6816
9.70	0.7105
9.80	0.7428
9.90	0.7655
10.0	0.7902
10.2	0.8232
10.4	0.8538
10.6	0.8840
10.8	0.8852
11.0	0.8938
11.2	0.8992
11.4	0.9054
11.6	0.9123
11.8	0.9197
12.0	0.9201
12.2	0.9144
12.4	0.9002
12.6	0.8903
12.8	0.8778
13.0	0.8865
13.2	0.8950
13.4	0.8999
13.6	0.9083
13.8	0.9162
14.0	0.9207
14.2	0.9251
14.4	0.8525
14.6	0.9324
16.0	0.9586

λ	ϵ
CURVE 10 T = 293.	
7.00	0.9994
7.10	0.9996
7.20	0.9999
7.30	0.9999
7.40	0.9995
7.50	0.9985
7.60	0.9963
7.70	0.9904
7.80	0.9796
7.90	0.9489
8.00	0.8649
8.10	0.7319
8.20	0.6963
8.30	0.6936
8.40	0.6640
8.50	0.6318
8.60	0.5784
8.65	0.5387
8.70	0.4793
8.75	0.4334
8.80	0.3675
8.85	0.3206
8.90	0.2982
8.95	0.2813
9.00	0.3296
9.05	0.3824
9.10	0.5351
9.15	0.4699
9.20	0.5256
9.30	0.5473
9.35	0.5836
9.40	0.6894
9.50	0.6567
9.60	0.6871
9.70	0.7159
9.80	0.7479
9.90	0.7705
10.0	0.7950
10.2	0.8335

λ	ϵ
CURVE 10(CONT.)	
10.4	0.8548
10.6	0.8874
10.6	0.8886
11.0	0.8971
11.2	0.9023
11.4	0.9085
11.6	0.9152
11.8	0.9225
12.0	0.9229
12.2	0.9172
12.4	0.9034
12.6	0.8937
12.8	0.8814
13.0	0.8899
13.2	0.8982
13.4	0.9030
13.6	0.9113
13.8	0.9190
14.0	0.9234
14.2	0.9277
14.4	0.8567
14.6	0.9348
16.0	0.9602
CURVE 11 T = 293.	
7.00	0.9994
7.10	0.9996
7.20	0.9999
7.30	0.9999
7.40	0.9995
7.50	0.9985
7.60	0.9969
7.70	0.9906
7.80	0.9800
7.90	0.9580
8.00	0.8681
8.10	0.7370
8.20	0.6902

TABLE 11-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE 11(CONT.)		CURVE 11(CONT.)		CURVE 12(CONT.)		CURVE 13(CONT.)		CURVE 13(CONT.)		CURVE 14(CONT.)	
8.30	0.6970	13.2	0.8990	9.15	0.4753	7.10	0.9936	10.8	0.8886	8.50	0.6318
8.40	0.6668	13.4	0.9038	9.20	0.5312	7.20	0.9999	11.0	0.8971	8.60	0.5784
8.50	0.6344	13.6	0.9120	9.30	0.5529	7.30	0.9999	11.2	0.9023	8.65	0.5386
8.60	0.5809	13.8	0.9197	9.35	0.5894	7.40	0.9995	11.4	0.9085	8.70	0.4793
8.65	0.5409	14.0	0.9241	9.40	0.6949	7.50	0.9985	11.6	0.9152	8.75	0.4334
8.70	0.4814	14.2	0.9283	9.50	0.6623	7.60	0.9969	11.8	0.9225	8.80	0.3675
8.75	0.4353	14.4	0.8577	9.60	0.6926	7.70	0.9934	12.0	0.9229	8.85	0.3205
8.80	0.3692	14.6	0.9354	9.70	0.7212	7.80	0.9796	12.2	0.9172	8.90	0.2982
8.85	0.3220	16.0	0.9606	9.80	0.7531	7.90	0.9489	12.4	0.9034	8.95	0.2813
8.90	0.2994			9.90	0.7754	8.00	0.8649	12.6	0.8937	9.00	0.3296
8.95	0.2824	CURVE 12		10.0	0.7997	8.10	0.7319	12.8	0.8814	9.05	0.3824
9.00	0.3307	T = 293.		10.2	0.8379	8.20	0.6863	13.0	0.8899	9.10	0.5351
9.05	0.3637			10.4	0.8583	8.30	0.6936	13.2	0.8982	9.15	0.4699
9.10	0.5365	7.00	0.9994	10.6	0.8909	8.40	0.6640	13.4	0.9030	9.20	0.5256
9.15	0.4713	7.10	0.9996	10.8	0.8920	8.50	0.6318	13.6	0.9113	9.30	0.5473
9.20	0.5270	7.20	0.9999	11.0	0.9004	8.60	0.5784	13.8	0.9190	9.35	0.5836
9.30	0.5487	7.30	0.9999	11.2	0.9055	8.65	0.5387	14.0	0.9234	9.40	0.6894
9.35	0.5851	7.40	0.9995	11.4	0.9115	8.70	0.4793	14.2	0.9277	9.50	0.6567
9.40	0.6908	7.50	0.9986	11.6	0.9181	8.75	0.4334	14.4	0.8567	9.60	0.6871
9.50	0.6581	7.60	0.9971	11.8	0.9251	8.80	0.3675	14.6	0.9348	9.70	0.7159
9.60	0.6885	7.70	0.9911	12.0	0.9256	8.85	0.3206	16.0	0.9602	9.80	0.7479
9.70	0.7172	7.80	0.9813	12.2	0.9201	8.90	0.2982			9.90	0.7705
9.80	0.7492	7.90	0.9536	12.4	0.9066	8.95	0.2813	CURVE 14		10.0	0.7950
9.90	0.7717	8.00	0.8777	12.6	0.8970	9.00	0.3296	T = 293.		10.2	0.8335
10.0	0.7961	8.10	0.7503	12.8	0.8849	9.05	0.3824			10.4	0.8548
10.2	0.8346	8.20	0.7008	13.0	0.8933	9.10	0.5351	7.00	0.9994	10.6	0.8874
10.4	0.8558	8.30	0.7062	13.2	0.9014	9.15	0.4699	7.10	0.9996	10.8	0.8886
10.6	0.8863	8.40	0.6747	13.4	0.9062	9.20	0.5256	7.20	0.9999	11.0	0.8971
10.8	0.8895	8.50	0.6419	13.6	0.9142	9.30	0.5473	7.30	0.9999	11.2	0.9023
11.0	0.8979	8.60	0.5878	13.8	0.9218	9.35	0.5836	7.40	0.9995	11.4	0.9085
11.2	0.9031	8.65	0.5475	14.0	0.9261	9.40	0.6894	7.50	0.9985	11.6	0.9152
11.4	0.9092	8.70	0.4874	14.2	0.9302	9.50	0.6567	7.60	0.9969	11.8	0.9225
11.6	0.9159	8.75	0.4409	14.4	0.8609	9.60	0.6871	7.70	0.9904	12.0	0.9229
11.8	0.9231	8.80	0.3749	14.6	0.9372	9.70	0.7159	7.80	0.9796	12.2	0.9172
12.0	0.9235	8.85	0.3261	16.0	0.9618	9.80	0.7479	7.90	0.9489	12.4	0.9034
12.2	0.9179	8.90	0.3032			9.90	0.7705	8.00	0.8648	12.6	0.8937
12.4	0.9042	8.95	0.2856	CURVE 13		10.0	0.7950	8.10	0.7319	12.8	0.8814
12.6	0.8945	9.00	0.3342	T = 293.		10.2	0.8335	8.20	0.6863	13.0	0.8899
12.8	0.8823	9.05	0.3974			10.4	0.8548	8.30	0.6936	13.2	0.8982
13.0	0.8907	9.10	0.5409	7.00	0.9994	10.6	0.8874	8.40	0.6640	13.4	0.9030

TABLE 11-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε
CURVE 14(CONT.)	
13.6	0.9113
13.8	0.9190
14.0	0.9234
14.2	0.9277
14.4	0.8567
14.6	0.9348
16.0	0.9602
CURVE 15	
T = 293.	
7.00	0.9994
7.10	0.9996
7.20	0.9999
7.30	0.9999
7.40	0.9995
7.50	0.9985
7.60	0.9969
7.70	0.9904
7.80	0.9796
7.90	0.9488
8.00	0.8643
8.10	0.7307
8.20	0.6856
8.30	0.6931
8.40	0.6637
8.50	0.6316
8.60	0.5782
8.65	0.5385
8.70	0.4792
8.75	0.4334
8.80	0.3675
8.85	0.3206
8.90	0.2982
8.95	0.2813
9.00	0.3296
9.05	0.3824
9.10	0.5351
9.15	0.4699
9.20	0.5256
CURVE 15(CONT.)	
9.30	0.5473
9.35	0.5836
9.40	0.6894
9.50	0.6567
9.60	0.6871
9.70	0.7159
9.80	0.7479
9.90	0.7704
10.0	0.7949
10.2	0.8335
10.4	0.8548
10.6	0.8874
10.8	0.8886
11.0	0.8971
11.2	0.9023
11.4	0.9084
11.6	0.9152
11.8	0.9224
12.0	0.9228
12.2	0.9172
12.4	0.9034
12.6	0.8935
12.8	0.8813
13.0	0.8899
13.2	0.8982
13.4	0.9030
13.6	0.9113
13.8	0.9190
14.0	0.9234
14.2	0.9277
14.4	0.8567
14.6	0.9348
16.0	0.9602

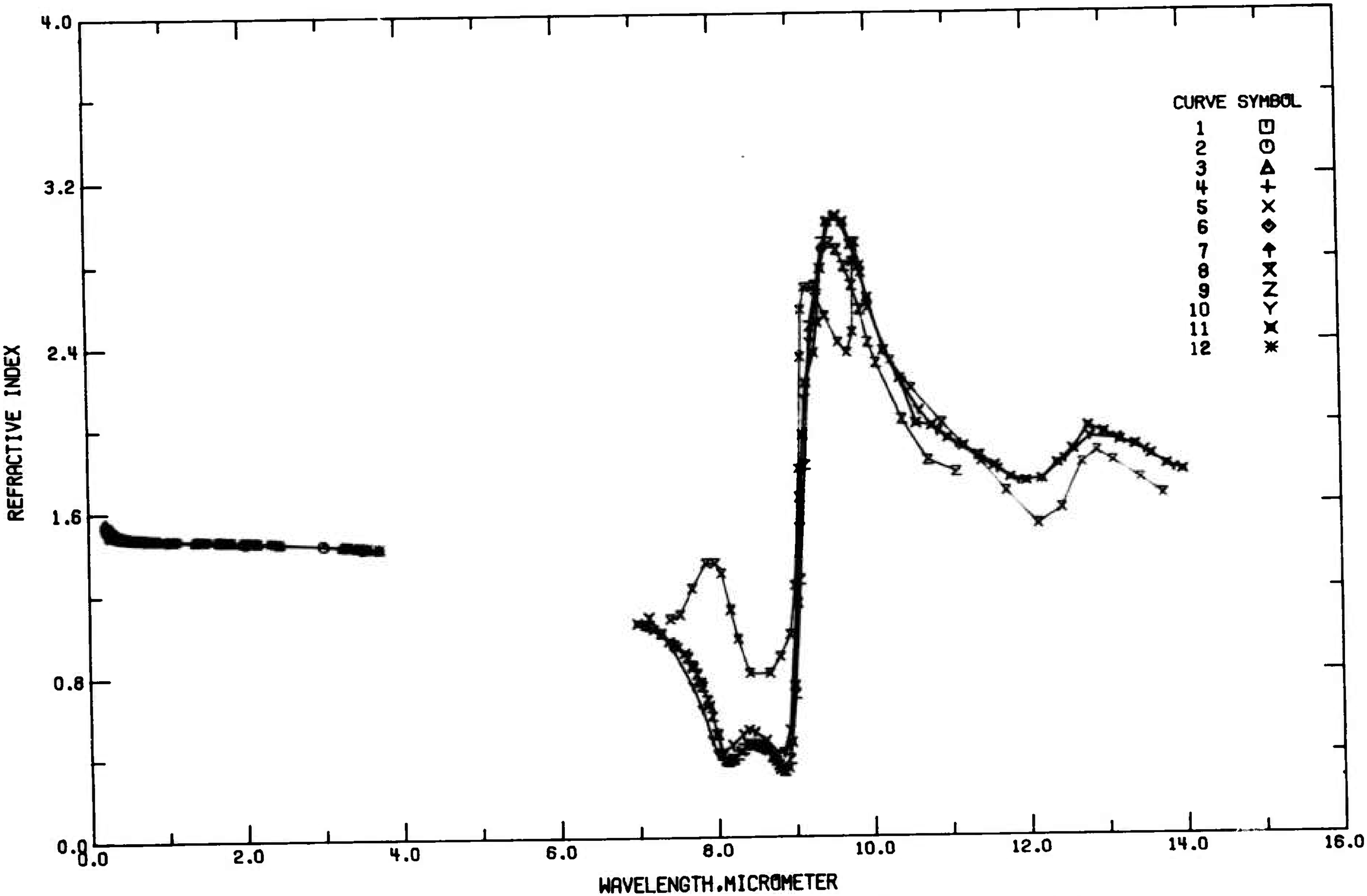


FIGURE 11-3. EXPERIMENTAL REFRACTIVE INDEX OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

TABLE 11-4. MEASUREMENT INFORMATION ON THE REFRACTIVE INDEX OF SILICA(VITREOUS) (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00010	Thermal American Fused Quartz Company	1970	0.24-0.77	297	Spectrosil Synthetic Fused Quartz	<0.00001 Ca, <0.00001 Fe, 0.000064 Na, <0.000002 Al, <0.000001 B, <0.0000004 Ga, <0.0000004 K, <0.0000001 P, <0.0000001 Mn, <0.00000002 As, <0.00000002 Cu, and 0.00000001 Sb (see Hetherington, G. and Bell, L.W., "Analysis of High-Purity Synthetic Vitreous Silicas," Physics and Chemistry of Glasses, 8(5), 206-8, 1967, [A00011]).
2	A00010	Thermal American Fused Quartz Company	1970	0.41-3.5	293	Vitreosil	99.8+ SiO_2; measurement temperature not given explicitly, assumed to be 293 K.
3	T76891	Corning Glass Works	1971	0.21-3.7	293	Corning Code 7940 Fused Silica	Typical analysis 0.0010-0.0100 Cl, 0.00001-0.0001 Ca, 0.00001-0.0010 Ti, 0.000005-0.0005 Al, 0.000005-0.00005 B, 0.000005-0.00005 Zn, 0.000001-0.00001 Bi, 0.000001-0.000005 Cu, 0.000001-0.0005 Fe, 0.000001-0.00001 K, 0.000001-0.00001 Mg, 0.000001-0.0001 Na, 0.000001-0.00001 P, 0.000001-0.00001 V, 0.0000001-0.0000005 As, 0.0000001-0.000005 Cr, 0.0000001-0.000001 Mn, and 0.0000001-0.0000005 Sb; maximum total impurities other than water do not exceed 0.01, water content estimated at 0.1 or less; amorphous; made by flame hydrolysis.
4	E21758	Malitson, I.H.	1965	0.21-3.7	293	Dynasil High-Purity Synthetic Fused Silica	Material submitted for testing was from four different production runs.
5	E21758	Malitson, I.H.	1965	0.21-3.7	293	General Electric Type 151	Material submitted for testing was from four different production runs.
6	E21758	Malitson, I.H.	1965	0.21-3.7	293	Corning Code 7940 Fused Silica	Material submitted for testing was from four different production runs.
7	E21758	Malitson, I.H.	1965	0.21-3.7	293	Fused Silica	Refractive index for high-purity optical quality fused silica made by three companies determined; materials Corning 7940 fused silica, Dynasil high purity synthetic fused silica, and General Electric type 151; minimum deviation method used; data fitted to three-term Sellmeier dispersion equation $n^2 - 1 = (0.6961663\,\lambda^2/(\lambda^2 - (0.0684043)^2)) + (0.4079426\,\lambda^2/(\lambda^2 - (0.1162414)^2)) + (0.8974794\,\lambda^2/(\lambda^2 - (9.896161)^2))$ with λ in μm; average of absolute values of residuals = 10.5×10^{-6}; data reported here calculated from above expression.
8	E64850	Crozier, D. and Douglas, R.W.	1965	7.4-14.8	293	Fused Silica	100 SiO_2; blown films prepared, selected areas stuck on copper wire loops and absorption spectra determined on a Grubb Parsons double-beam spectrometer; thin film method of Blain and Douglas used to analyze spectra to give refractive index and absorption index; measurement temperature not given explicitly, assumed to be 293 K.
9	T60820	Zolotarev, V.M.	1970	7.1-11	293	Fused Quartz	Several overlapping methods used to determine refractive index; measurement temperature not explicitly given, assumed to be 293 K.
10	E64849	Popova, S.L., Tolstykh, T.S., and Vorobev, V.T.	1972	7.1-50	293	Amorphous Quartz	Total impurity content ($CaCO_3$, sodium chloride, and oxides of Al, Mg, Cu, Ca, and Fe) <0.007; SiO_2 samples of grades KU and KI used; refractive index n and absorption index k derived from reflectance spectra; measurement temperature not given explicitly, assumed to be 293 K.
11	A00012	Champetier, R.J. and Friese, G.J.	1974	7.0-26	293	Fused Silica	Refractive index values for wavelengths shorter than 9 μm based on data in [T60820] (curve 9 above), for longer wavelengths based on data in [E64849] (curve 10 above).

TABLE 11-4. MEASUREMENT INFORMATION ON THE REFRACTIVE INDEX OF SILICA(VITREOUS) (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, µm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
12	E19326	Jerrard, H.G. and Turpin, J.	1965	0.20-0.30	291.7	Optical Quality Fused Silica, Spectrosil A	Specimen supplied by the Thermal Syndicate, Wallsend, England; light source was copper arc and wavelength values taken from table (44th edition of Handbook of Chemistry and Physics); values reported are mean values for three different experiments conducted in air; most of the deviations found in the fifth decimal place in range 0.00002 to 0.00004.

TABLE 11-5. EXPERIMENTAL REFRACTIVE INDEX OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFRACTIVE INDEX, n]

λ	n
CURVE 1	
T = 297.	
0.2378	1.51478
0.2536	1.50559
0.2654	1.50002
0.2803	1.49409
0.2967	1.48875
0.3023	1.48718
0.3132	1.48434
0.3341	1.47976
0.3650	1.47456
0.4046	1.46965
0.4358	1.46673
0.4799	1.46354
0.4861	1.46317
0.5460	1.46011
0.5875	1.45850
0.6438	1.45674
0.6562	1.45641
0.7682	1.45393
CURVE 2	
T = 293.	
0.4101	1.46973
0.4307	1.46686
0.4861	1.46333
0.5269	1.46029
0.5895	1.45866
0.6562	1.45655
0.7183	1.45530
1.0000	1.447
2.0000	1.432
3.0000	1.418
3.5000	1.40
CURVE 3	
T = 293.	
0.2138	1.53426
0.2144	1.53370

λ	n
CURVE 3(CONT.)	
0.2267	1.52281
0.2302	1.52005
0.2482	1.50839
0.2652	1.50000
0.2752	1.49592
0.2803	1.49403
0.2967	1.48872
0.3021	1.48719
0.3341	1.47976
0.3466	1.47745
0.3610	1.47512
0.4046	1.46961
0.4358	1.46669
0.4678	1.46429
0.4861	1.46313
0.5460	1.46007
0.5875	1.45846
0.5892	1.45640
0.6438	1.45670
0.6562	1.45637
0.6678	1.45607
0.7065	1.45515
0.8521	1.45246
0.8943	1.45184
1.0829	1.44940
1.3622	1.44619
1.4695	1.44498
1.6606	1.44265
1.7091	1.44206
1.8130	1.44069
1.9700	1.43853
2.1526	1.43574
2.4374	1.43093
3.2439	1.41314
3.3026	1.41156
3.422	1.40822
3.5564	1.40414
3.7067	1.39937

λ	n
CURVE 4	
T = 293.	
0.2138	1.53426
0.2144	1.53370
0.2267	1.52281
0.2302	1.52005
0.2378	1.51475
0.2399	1.51336
0.2482	1.50839
0.2652	1.50000
0.2698	1.49804
0.2752	1.49592
0.2803	1.49403
0.2893	1.49101
0.2967	1.48872
0.3021	1.48719
0.3302	1.48054
0.3341	1.47976
0.3403	1.47858
0.3466	1.47745
0.3610	1.47512
0.3650	1.47452
0.4046	1.46961
0.4358	1.46669
0.4678	1.46429
0.4861	1.46313
0.5085	1.46186
0.5460	1.46007
0.5769	1.45884
0.5790	1.45877
0.5875	1.45846
0.5892	1.45840
0.6438	1.45670
0.6562	1.45637
0.6678	1.45607
0.7065	1.45515
0.8521	1.45246
0.8943	1.45184
1.0139	1.45024
1.0829	1.44940
1.1286	1.44887

λ	n
CURVE 4(CONT.)	
1.3622	1.44619
1.3950	1.44564
1.4695	1.44498
1.5295	1.44427
1.6606	1.44265
1.681	1.44240
1.6932	1.44225
1.7091	1.44206
1.8130	1.44069
1.9700	1.43853
2.0581	1.43721
2.3254	1.43292
2.4374	1.43093
3.2439	1.41314
3.2668	1.41253
3.3026	1.41156
3.422	1.40822
3.5070	1.40565
3.5564	1.40414
3.7067	1.39937
CURVE 5	
T = 293.	
0.2138	1.53427
0.2144	1.53370
0.2267	1.52282
0.2302	1.52005
0.2378	1.51474
0.2399	1.51337
0.2482	1.50840
0.2652	1.50001
0.2698	1.49805
0.2752	1.49591
0.2803	1.49402
0.2893	1.49101
0.2967	1.48873
0.3021	1.48719
0.3302	1.48054
0.3341	1.47977

λ	n
CURVE 5(CONT.)	
0.3403	1.47857
0.3466	1.47745
0.3610	1.47512
0.3650	1.47451
0.4046	1.46962
0.4358	1.46669
0.4678	1.46429
0.4861	1.46313
0.5085	1.46186
0.5460	1.46007
0.5769	1.45885
0.5790	1.45877
0.5875	1.45846
0.5892	1.45841
0.6438	1.45671
0.6562	1.45637
0.6678	1.45607
0.7065	1.45515
0.8521	1.45247
0.8943	1.45184
1.0139	1.45024
1.0829	1.44941
1.1286	1.44887
1.3622	1.44620
1.3950	1.44583
1.4695	1.44498
1.5295	1.44426
1.6606	1.44265
1.681	1.44242
1.6932	1.44226
1.7091	1.44205
1.8130	1.44069
1.9700	1.43850
2.0581	1.43721
2.1526	1.43577
2.3254	1.43292
2.4374	1.43094
3.2939	1.41314
3.2668	1.41253
3.3026	1.41156

λ	n
CURVE 5(CONT.)	
3.422	1.40821
3.5070	1.40566
3.5564	1.40415
3.7067	1.39938
CURVE 6	
T = 293.	
0.2138	1.53427
0.2144	1.53371
0.2267	1.52282
0.2302	1.52005
0.2378	1.51474
0.2399	1.51337
0.2482	1.50840
0.2652	1.49999
0.2698	1.49805
0.2752	1.49591
0.2803	1.49403
0.2893	1.49100
0.2967	1.48872
0.3021	1.48718
0.3302	1.48054
0.3341	1.47975
0.3403	1.47859
0.3466	1.47745
0.3610	1.47513
0.3650	1.47452
0.4046	1.46961
0.4358	1.46669
0.4678	1.46429
0.4861	1.46313
0.5085	1.46186
0.5460	1.46008
0.5769	1.45885
0.5790	1.45877
0.5875	1.45846
0.5892	1.45841
0.6438	1.45671
0.6562	1.45637

TABLE 11-5. EXPERIMENTAL REFRACTIVE INDEX OF SILICA (VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFRACTIVE INDEX, n]

λ	n	λ	n	λ	n	λ	n	λ	n	λ	n
CURVE 6 (CONT.)		CURVE 7 (CONT.)		CURVE 7 (CONT.)		CURVE 8 (CONT.)		CURVE 9 (CONT.)		CURVE 10 (CONT.)	
0.6678	1.45607	0.2698	1.49904	1.9700	1.43851	9.921	2.74	8.772	0.35	9.259	2.40
0.7065	1.45515	0.2752	1.49591	2.0581	1.43722	10.01	2.57	8.850	0.32	9.346	2.62
0.8521	1.45247	0.2803	1.49403	2.1526	1.43576	10.22	2.31	8.929	0.38	9.434	2.83
0.8943	1.45184	0.2893	1.49099	2.3254	1.43292	10.54	2.17	9.009	0.70	9.524	2.98
1.0139	1.45024	0.2967	1.48873	2.4374	1.43095	10.93	2.00	9.091	1.25	9.615	3.01
1.0829	1.44941	0.3021	1.48719	3.2439	1.41311	11.42	1.81	9.174	1.80	9.804	2.87
1.1286	1.44887	0.3302	1.48053	3.2668	1.41250	11.74	1.66	9.259	2.48	10.00	2.62
1.3622	1.44620	0.3341	1.47976	3.3026	1.41153	12.14	1.51	9.346	2.68	10.20	2.36
1.3950	1.44583	0.3403	1.47858	3.422	1.40819	12.45	1.58	9.434	2.88	10.42	2.20
1.4695	1.44497	0.3466	1.47746	3.5070	1.40557	12.71	1.80	9.524	2.88	10.64	2.06
1.5295	1.44427	0.3610	1.47512	3.5564	1.40417	12.90	1.86	9.615	2.85	10.87	1.96
1.6606	1.44265	0.3650	1.47453	3.7067	1.39938	13.11	1.81	9.709	2.77	11.11	1.90
1.681	1.44241	0.4046	1.46961			13.46	1.72	9.804	2.68	11.36	1.84
1.6932	1.44226	0.4358	1.46669	CURVE 8		13.74	1.64	9.901	2.56	11.63	1.77
1.7091	1.44205	0.4678	1.46429	T = 293.		14.01	1.60	10.00	2.40	11.90	1.71
1.8130	1.44069	0.4861	1.46312			14.84	1.58	10.10	2.30	12.20	1.72
1.9700	1.43852	0.5085	1.46186	7.413	1.07			10.42	2.02	12.50	1.82
2.0581	1.43722	0.5460	1.46007	7.541	1.09	CURVE 9		10.75	1.82	12.82	1.93
2.1526	1.43574	0.5769	1.45894	7.698	1.21	T = 293.		11.11	1.76	13.16	1.92
2.3254	1.43291	0.5790	1.45876	7.880	1.33					13.51	1.86
2.4374	1.43093	0.5875	1.45646	8.000	1.33	7.143	1.04	CURVE 10		13.89	1.77
3.2439	1.41313	0.5892	1.45840	8.078	1.28	7.299	1.00	T = 293.		14.29	1.72
3.2668	1.41252	0.6438	1.45670	8.190	1.11	7.463	0.94			14.71	1.67
3.3026	1.41156	0.6562	1.45636	8.278	0.97	7.634	0.88	7.143	1.08	15.15	1.60
3.422	1.40822	0.6678	1.45606	8.425	0.80	7.692	0.84	7.407	0.95	15.63	1.54
3.5070	1.40565	0.7065	1.45514	8.681	0.80	7.752	0.80	7.692	0.74	16.13	1.47
3.5564	1.40414	0.8521	1.45246	8.818	0.88	7.813	0.74	7.813	0.62	16.67	1.41
3.7067	1.39936	0.8943	1.45183	8.945	0.99	7.874	0.67	7.937	0.47	17.24	1.35
		1.0139	1.45024	9.017	1.22	7.937	0.59	8.000	0.40	17.85	1.30
CURVE 7		1.0829	1.44940	9.083	1.78	8.000	0.50	8.065	0.41	18.52	1.12
T = 293.		1.1286	1.44886	9.124	2.33	8.065	0.40	8.197	0.45	19.23	0.99
		1.3622	1.44621	9.141	2.56	8.130	0.37	8.333	0.50	20.00	0.64
0.2138	1.53430	1.3950	1.44583	9.191	2.67	8.197	0.38	8.403	0.52	20.41	0.52
0.2144	1.53372	1.4695	1.44497	9.234	2.67	8.264	0.40	8.475	0.51	20.83	0.98
0.2267	1.52275	1.5295	1.44268	9.452	2.53	8.333	0.43	8.621	0.47	21.05	1.37
0.2302	1.52008	1.6606	1.44267	9.615	2.40	8.403	0.45	8.772	0.41	21.28	1.84
0.2378	1.51472	1.681	1.44241	9.728	2.35	8.475	0.45	8.850	0.41	21.74	2.45
0.2399	1.51336	1.6932	1.44226	9.894	2.45	8.547	0.44	8.929	0.52	22.22	2.68
0.2482	1.50839	1.7091	1.44205	9.814	2.79	8.621	0.43	9.091	1.50	22.73	2.77
0.2652	1.50002	1.8130	1.44069	9.852	2.89	8.696	0.39	9.174	2.12	23.26	2.79

TABLE 11-5. EXPERIMENTAL REFRACTIVE INDEX OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFRACTIVE INDEX, n]

λ	n
CURVE 10(CONT.)	
23.81	2.77
24.39	2.71
25.00	2.62
28.57	2.33
33.33	2.19
40.00	2.12
50.00	2.06
CURVE 11	
T = 293.	
7.0	1.05
7.1	1.04
7.2	1.02
7.3	1.00
7.4	0.96
7.5	0.93
7.6	0.90
7.7	0.83
7.8	0.76
7.9	0.645
8.0	0.50
8.1	0.374
8.2	0.38
8.3	0.417
8.4	0.45
8.5	0.448
8.6	0.433
8.65	0.42
8.7	0.39
8.75	0.37
8.8	0.33
8.85	0.32
8.9	0.336
8.95	0.46
9.0	0.74
9.05	1.14
9.1	1.64
9.15	1.95
9.2	2.20

λ	n
CURVE 11(CONT.)	
9.3	2.35
9.35	2.50
9.4	2.76
9.5	2.98
9.6	3.00
9.7	2.98
9.8	2.87
9.9	2.77
10.0	2.62
10.2	2.36
10.4	2.22
10.6	2.00
10.8	1.99
11.0	1.93
11.2	1.89
11.4	1.84
11.6	1.79
11.8	1.73
12.0	1.71
12.2	1.72
12.4	1.80
12.6	1.87
12.8	1.98
13.0	1.95
13.2	1.91
13.4	1.89
13.6	1.84
13.8	1.79
14.0	1.76
14.2	1.73
14.4	1.71
14.6	1.68
16.0	1.48
18.0	1.26
19.0	1.02
20.0	0.64
20.5	0.52
21.0	1.30
21.5	2.24
22.0	2.59

λ	n
CURVE 11(CONT.)	
23.0	2.77
24.0	2.75
26.0	2.60
CURVE 12	
T = 291.7	
0.1999	1.55037
0.2025	1.54700
0.2035	1.54570
0.2037	1.54553
0.2043	1.54471
0.2054	1.54337
0.2087	1.53956
0.2104	1.53772
0.2112	1.53695
0.2122	1.53581
0.2125	1.53549
0.2135	1.53447
0.2149	1.53318
0.2179	1.53029
0.2189	1.52921
0.2192	1.52898
0.2210	1.52737
0.2218	1.52670
0.2242	1.52463
0.2246	1.52427
0.2276	1.52193
0.2294	1.52055
0.2336	1.51752
0.2369	1.51521
0.2400	1.51324
0.2403	1.51333
0.2424	1.51172
0.2473	1.50886
0.2485	1.50816
0.2506	1.50704
0.2529	1.50577
0.2544	1.50500
0.2571	1.50365

λ	n
CURVE 12(CONT.)	
0.2590	1.50272
0.2599	1.50231
0.2609	1.50188
0.2618	1.50139
0.2666	1.49932
0.2689	1.49834
0.2700	1.49781
0.2713	1.49735
0.2718	1.49714
0.2745	1.49610
0.2769	1.49516
0.2824	1.49321
0.2837	1.49274
0.2877	1.49138
0.2961	1.48879

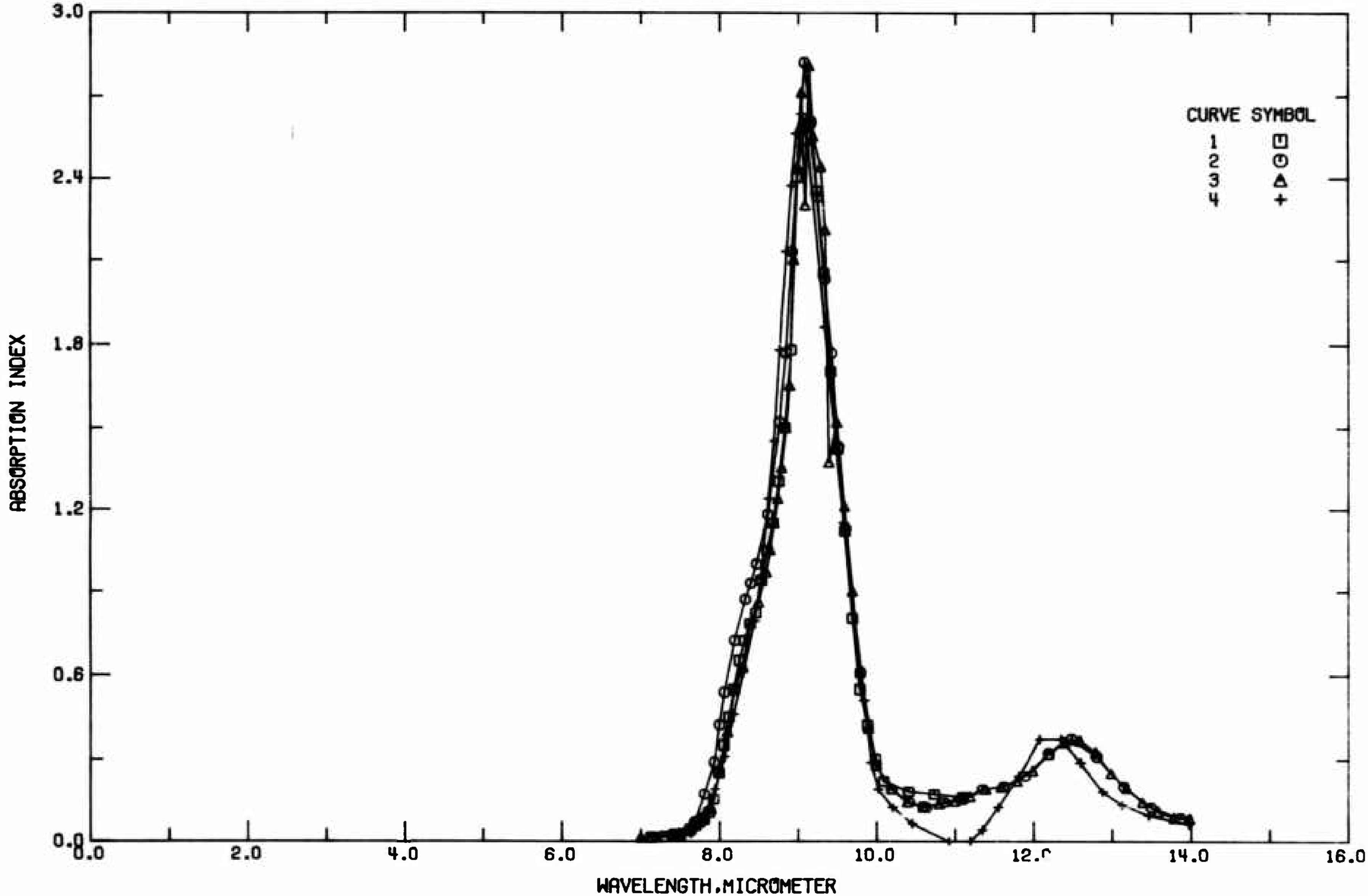


FIGURE 11-4. EXPERIMENTAL ABSORPTION INDEX OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

TABLE 11-6. MEASUREMENT INFORMATION ON THE ABSORPTION INDEX OF SILICA(VITREOUS) (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	E45777	Zolotorev, V.M.	1970	7.1-11	~293	Fused Quartz	Several overlapping methods used to determine absorption index; measurement temperature not explicitly given, assumed to be 293 K.
2	E64849	Popova, S.I., Tolstykh, T.S., and Vorobev, V.T.	1972	7.1-50	293	Amorphous Quartz	Total impurity content ($CaCO_3$, sodium chloride, and oxides of Al, Mg, Cu, Ca, and Fe) <0.007; SiO_2 samples of grades KU and KI used; refractive index n and absorption index k derived from reflectance spectra; measurement temperature not given explicitly, assumed to be 293 K.
3	A00012	Champetier, R.J. and Friese, G.J.	1974	7.0-26.0	293	Fused Silica	Absorption index values for wavelengths shorter than 9 μm based on data in [T60820] (curve 1 above), for longer wavelengths based on data in [E64849] (curve 2 above).
4	E64850	Crozier, D. and Douglas, R.W.	1965	7.5-14	293	Fused Silica	100 SiO_2; blown films prepared, selected areas stuck on copper wire loops and absorption spectra determined on a Grubb Parsons double-beam spectrometer; thin film method of Blain and Douglas used to analyze spectra to give refractive index and absorption index; measurement temperature not given explicitly, assumed to be 293 K.

TABLE 11-7. EXPERIMENTAL ABSORPTION INDEX OF SILICA (VITREOUS) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTION INDEX, k]

λ	k
CURVE 1	
T = 293.	
7.143	0.014
7.299	0.016
7.463	0.022
7.634	0.041
7.692	0.055
7.752	0.068
7.813	0.080
7.874	0.10
7.937	0.15
8.000	0.25
8.065	0.35
8.130	0.45
8.197	0.55
8.264	0.65
8.333	0.72
8.403	0.78
8.475	0.82
8.547	0.94
8.621	1.05
8.696	1.15
8.772	1.30
8.850	1.50
8.929	1.78
9.009	2.40
9.091	2.58
9.174	2.60
9.259	2.35
9.346	2.05
9.434	1.70
9.524	1.42
9.615	1.12
9.709	0.80
9.804	0.55
9.301	0.42
10.00	0.30
10.10	0.22
10.42	0.18
10.75	0.17
11.11	0.16

λ	k
CURVE 2	
T = 293.	
7.143	0.012
7.407	0.023
7.692	0.065
7.813	0.17
7.937	0.29
8.000	0.42
8.065	0.54
8.197	0.72
8.333	0.87
8.403	0.93
8.475	1.00
8.621	1.18
8.772	1.52
8.850	1.77
8.929	2.13
9.091	2.82
9.174	2.60
9.259	2.33
9.346	2.03
9.434	1.77
9.524	1.43
9.615	1.13
9.804	0.61
10.00	0.28
10.20	0.19
10.42	0.14
10.60	0.123
10.64	0.12
10.87	0.14
11.11	0.15
11.36	0.19
11.63	0.20
11.90	0.24
12.20	0.32
12.50	0.37
12.82	0.31
13.16	0.20
13.51	0.12
13.89	0.08

λ	k
CURVE 2 (CONT.)	
14.29	0.08
14.71	0.08
15.15	0.08
15.63	0.10
16.13	0.13
16.67	0.14
17.24	0.19
17.86	0.24
18.52	0.32
19.23	0.42
20.00	0.87
20.41	1.39
20.83	2.16
21.05	2.39
21.28	2.30
21.74	1.92
22.22	1.52
22.73	1.18
23.26	0.94
23.81	0.71
24.39	0.54
25.00	0.41
28.57	0.16
33.33	0.11
40.00	0.05
50.00	0.03
CURVE 3	
T = 293.	
7.0	0.0137
7.1	0.0139
7.2	0.0144
7.3	0.0160
7.4	0.0187
7.5	0.0250
7.6	0.0365
7.7	0.0560
7.8	0.0750
7.9	0.1140

λ	k
CURVE 3 (CONT.)	
8.0	0.2500
8.1	0.3950
8.2	0.5570
8.3	0.6300
8.4	0.7800
8.5	0.8600
8.6	0.9700
8.65	1.0500
8.7	1.1500
8.75	1.2400
8.8	1.3500
8.85	1.5000
8.9	1.6500
8.95	2.1000
9.0	2.4400
9.05	2.7100
9.1	2.3000
9.15	2.8100
9.2	2.5500
9.3	2.4400
9.35	2.2100
9.4	1.3700
9.5	1.5200
9.6	1.2100
9.7	0.9000
9.8	0.6100
9.9	0.4100
10.0	0.2804
10.2	0.1900
10.4	0.1400
10.6	0.1210
10.8	0.1330
11.0	0.1430
11.2	0.1620
11.4	0.1900
11.6	0.1980
11.8	0.2210
12.0	0.2600
12.2	0.3200
12.4	0.3600

λ	k
CURVE 3 (CONT.)	
12.6	0.3650
12.8	0.3250
13.0	0.2500
13.2	0.1940
13.4	0.1400
13.6	0.1050
13.8	0.0820
14.0	0.0800
14.2	0.0800
14.4	0.0800
14.6	0.0800
16.0	0.1220
18.0	0.2750
19.0	0.3880
20.0	0.8700
20.5	1.5200
21.0	2.3700
21.5	2.1100
22.0	1.7200
23.0	1.0400
24.0	0.6100
26.0	0.2800
CURVE 4	
T = 293.	
7.485	0.03
7.634	0.03
7.758	0.06
7.849	0.11
7.943	0.19
8.065	0.31
8.183	0.46
8.306	0.61
8.453	0.79
8.532	0.95
8.628	1.24
8.696	1.45
8.772	1.78
8.857	2.13

λ	k
CURVE 4 (CONT.)	
8.921	2.37
8.985	2.56
9.050	2.63
9.132	2.52
9.346	1.86
9.588	1.15
9.852	0.51
9.940	0.29
10.03	0.19
10.21	0.12
10.46	0.06
10.93	0.00
11.20	0.00
11.36	0.04
11.56	0.12
11.82	0.24
12.09	0.37
12.36	0.37
12.61	0.29
12.89	0.18
13.14	0.13
13.48	0.09
13.99	0.06

b. Angular Spectral Emittance (Wavelength Dependence)

A total of 11 sets of experimental data were located for the wavelength dependence of the angular spectral emittance of vitreous silica. The data are listed in Table 11-10 and shown in Figures 11-5 and 11-6. Specimen characterization and measurement information for the data are given in Table 11-9.

All 11 sets apply to Optosil 1 and were measured at a specimen temperature of 373 K using the Honeywell spectral emissometer. The minima in the curves are closer to 8 μm than 9 μm which was the same phenomenon observed for Honeywell data in the normal spectral emittance section.

A set of provisional values for optically smooth vitreous silica at 293 K, a viewing angle θ' of 40°, and a wavelength range of 7.0 to 16.0 μm is listed in Table 11-8 and shown in Figure 11-5. The values were calculated using Eqs. (2.4-1) to (2.4-5) and Eq. (2.4-8). Equation (2.4-8) includes Kirchhoff's law equating the emittance to the absorptance. The index of refraction and absorption index data were taken from Champetier and Friese [A00012] as mentioned in the section on the wavelength dependence of the normal spectral emittance. Because the index of refraction and absorption index data are themself not evaluated and because good experimental data has not been located, the values for the angular spectral emittance are called provisional with an uncertainty which is thought to be within 30%.

TABLE 11-8. PROVISIONAL ANGULAR SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε
OPTICALLY SMOOTH θ'=40° T = 293		OPTICALLY SMOOTH θ'=40° T = 293 (CONT.)	
7.00	0.999	10.4	0.849
7.10	0.999	10.6	0.881
7.20	1.000	10.8	0.882
7.30	1.000	11.0	0.890
7.40	0.999	11.2	0.896
7.50	0.998	11.4	0.902
7.60	0.995	11.6	0.908
7.70	0.981	11.8	0.915
7.80	0.950	12.0	0.916
7.90	0.822	12.2	0.910
8.00	0.688	12.4	0.896
8.10	0.577	12.6	0.887
8.20	0.588	12.8	0.875
8.30	0.615	13.0	0.883
8.40	0.609	13.2	0.891
8.50	0.585	13.4	0.896
8.60	0.541	13.6	0.904
8.65	0.507	13.8	0.912
8.70	0.455	14.0	0.917
8.75	0.414	14.2	0.921
8.80	0.354	14.4	0.848
8.85	0.312	14.6	0.928
8.90	0.293	16.0	0.954
8.95	0.280		
9.00	0.330		
9.05	0.384		
9.10	0.534		
9.15	0.472		
9.20	0.527		
9.30	0.548		
9.35	0.584		
9.40	0.687		
9.50	0.656		
9.60	0.686		
9.70	0.714		
9.80	0.745		
9.90	0.767		
10.0	0.791		
10.2	0.828		

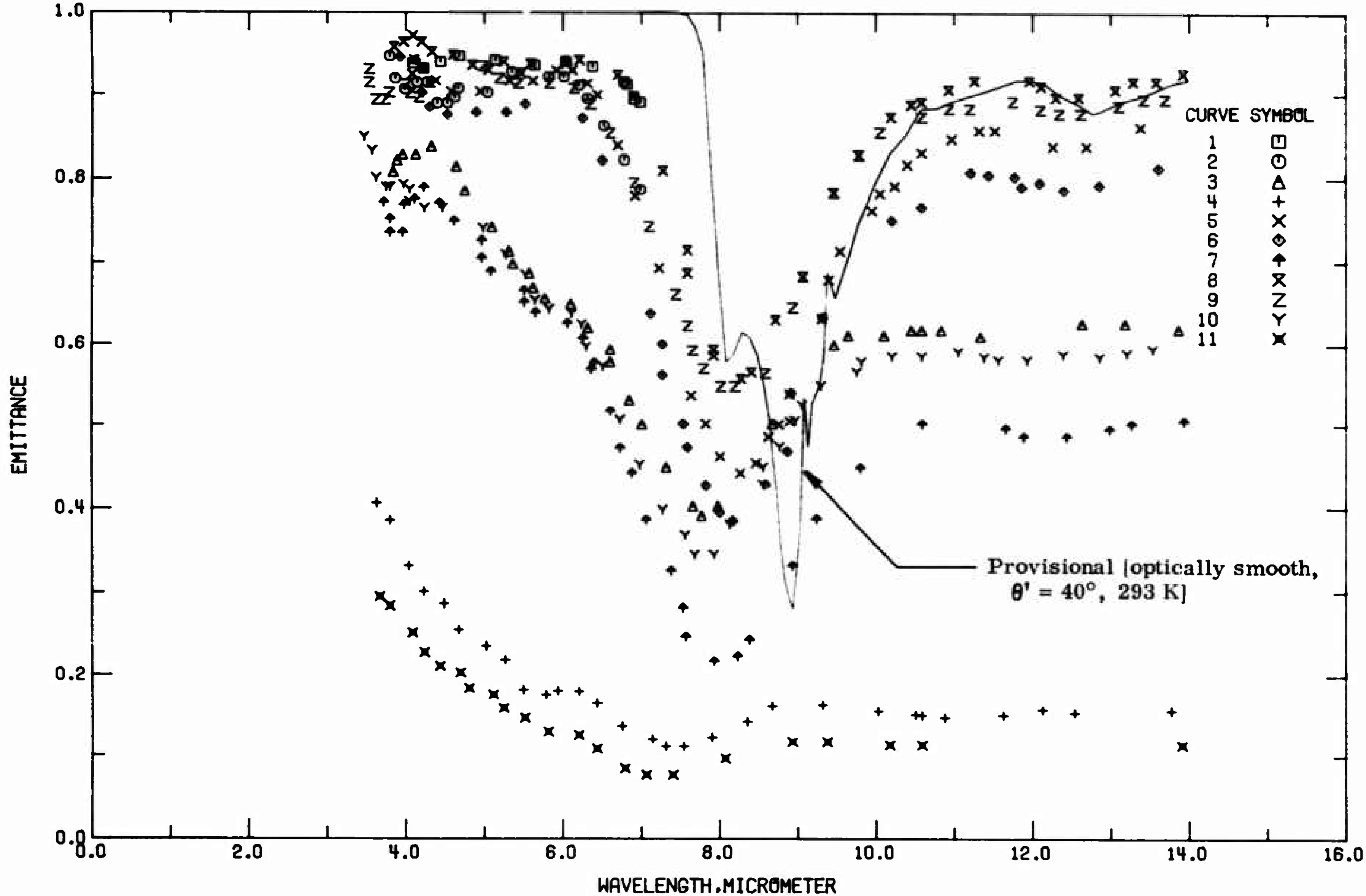


FIGURE 11-5. PROVISIONAL ANGULAR SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

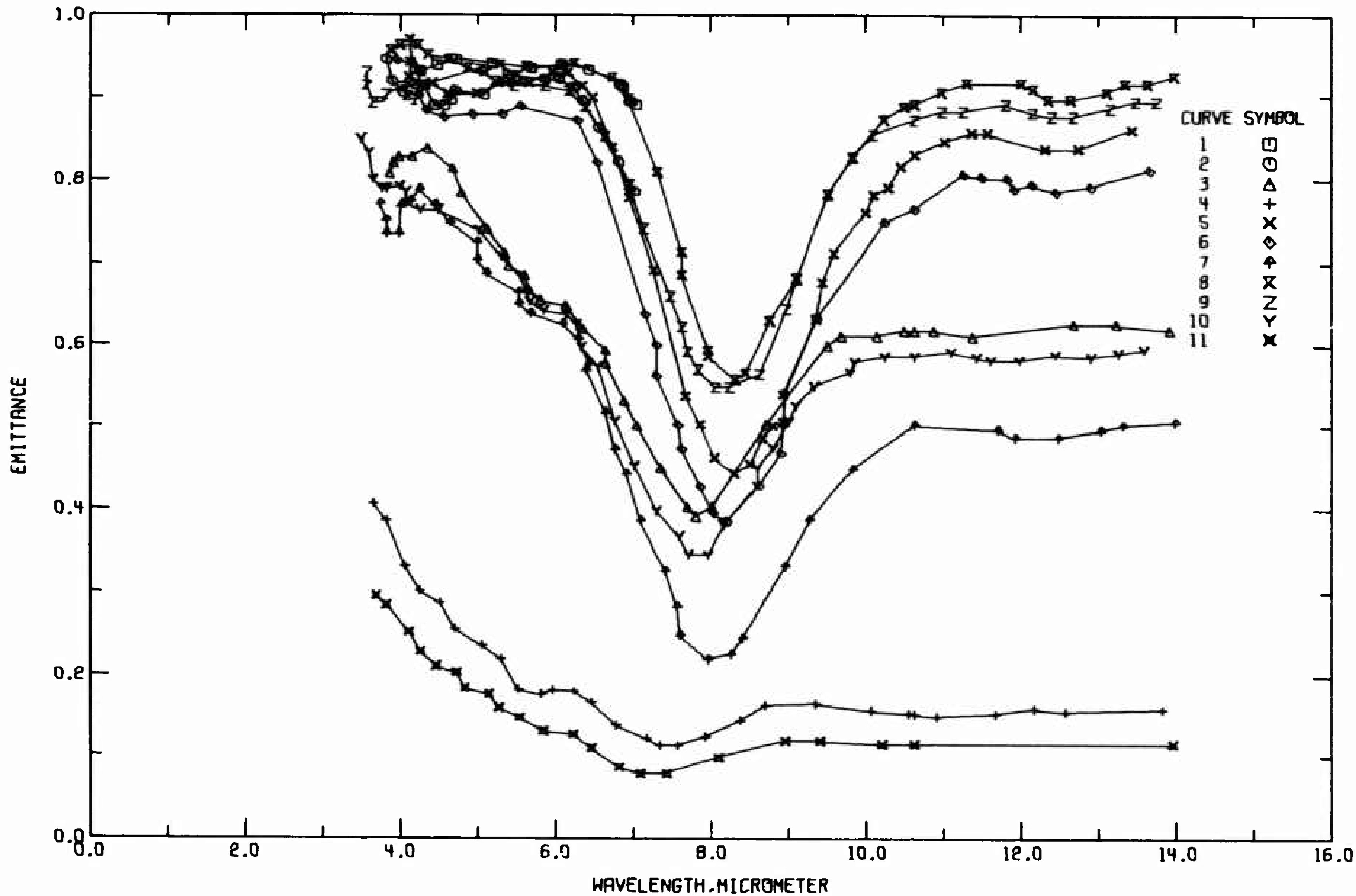


FIGURE 11-6. EXPERIMENTAL ANGULAR SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

TABLE 11-9. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL EMITTANCE OF SILICA (VITREOUS) (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00012	Champetier, R.J. and Friese, G.J.	1974	4.1-7.0	373	Optosil 1	Specimen thickness 0.125 in.; polished disk; Honeywell spectral emissometer used which includes a Leiss double prism monochromator with prisms of potassium or cesium bromide; computed system band width 0.19 μm; optics, chopper, and enclosure near 300 K while sample and black body reference are heated to 373 K; polarization of monochromator which is present has not been removed from data; 0° data taken but not reported, the 0° and 12° data were identical; emittance data for parallel polarization; a conclusion in this report [A00012] is that "Honeywell emissometer currently produces incorrect data at angles greater than 40 degrees and previously generated data cannot be used with confidence in their validity"; smooth values from figure; because of overlap of curves, data could not be extracted for full wavelength range for which data reported; $\theta' = 30°$.
2	A00012	Champetier, R.J. and Friese, G.J.	1974	3.8-7.0	373	Optosil 1	Similar to the above specimen; $\theta' = 40°$.
3	A00012	Champetier, R.J. and Friese, G.J.	1974	3.8-30	373	Optosil 1	Similar to the above specimen except data extracted for full wavelength range for which it is reported; $\theta' = 50°$.
4	A00012	Champetier, R.J. and Friese, G.J.	1974	3.6-30	373	Optosil 1	Similar to the above specimen except data reported for θ' of 70° and 75°, however, it could not be extracted due to overlap of curves; $\theta' = 60°$.
5	A00012	Champetier, R.J. and Friese, G.J.	1974	4.1-19	373	Optosil 1	Similar to the above specimen except data reported for perpendicular polarization and because of overlap of curves, data could not be extracted for full wavelength range; $\theta' = 30°$.
6	A00012	Champetier, R.J. and Friese, G.J.	1974	3.9-19	373	Optosil 1	Similar to the above specimen; $\theta' = 40°$.
7	A00012	Champetier, R.J. and Friese, G.J.	1974	3.7-30	373	Optosil 1	Similar to the above specimen except data extracted for full wavelength range for which it is reported; in addition, data reported for θ' of 60°, 70°, and 75°, however, it could not be extracted due to overlap of curves; $\theta' = 50°$.
8	A00012	Champetier, R.J. and Friese, G.J.	1974	3.9-20	373	Optosil 1	Similar to the above specimen except data reported for unpolarized radiation and because of overlap of curves, data could not be extracted for the full wavelength range for which data reported; $\theta' = 30°$.
9	A00012	Champetier, R.J. and Friese, G.J.	1974	3.5-20	373	Optosil 1	Similar to the above specimen; $\theta' = 40°$.
10	A00012	Champetier, R.J. and Friese, G.J.	1974	3.5-30	373	Optosil 1	Similar to the above specimen except data extracted for full wavelength range for which it is reported; $\theta' = 50°$.
11	A00012	Champetier, R.J. and Friese, G.J.	1974	3.7-30	373	Optosil 1	Similar to the above specimen except data reported for θ' of 70° and 75°, however, it could not be extracted due to the overlap of the curves; $\theta' = 60°$.

TABLE 11-10. EXPERIMENTAL ANGULAR SPECTRAL EMITTANCE OF SILICA (VITREOUS) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE 1		CURVE	3(CONT.)	CURVE	3(CONT.)	CURVE	3(CONT.)	CURVE	4(CONT.)	CURVE	4(CONT.)
T = 373.											
		3.89	0.820	16.93	0.619	25.86	0.598	5.79	0.176	21.90	0.135
4.10	0.936	3.96	0.827	17.41	0.587	26.36	0.548	5.94	0.181	22.08	0.144
4.23	0.930	4.13	0.827	17.71	0.595	26.49	0.519	6.21	0.180	22.53	0.156
4.45	0.938	4.33	0.837	17.94	0.612	26.63	0.512	6.44	0.166	22.76	0.149
4.69	0.945	4.65	0.813	18.15	0.631	26.86	0.526	6.76	0.137	22.95	0.153
5.15	0.940	4.76	0.784	18.35	0.631	26.86	0.547	7.15	0.121	23.14	0.153
5.65	0.934	5.10	0.740	18.66	0.621	26.79	0.590	7.32	0.112	23.36	0.158
6.05	0.939	5.32	0.712	19.06	0.623	26.96	0.621	7.55	0.112	23.67	0.148
6.39	0.932	5.37	0.697	19.74	0.574	27.26	0.648	7.91	0.123	23.89	0.148
6.79	0.914	5.58	0.686	20.04	0.557	27.49	0.648	8.36	0.143	24.03	0.142
6.83	0.911	5.63	0.669	20.17	0.535	27.71	0.643	8.68	0.162	24.25	0.149
6.92	0.893	5.78	0.656	20.27	0.514	27.82	0.628	9.33	0.164	24.45	0.147
7.00	0.889	6.11	0.649	20.49	0.501	27.82	0.610	10.04	0.156	24.67	0.207
		6.33	0.620	20.49	0.467	27.98	0.598	10.52	0.152	24.86	0.215
CURVE 2		6.62	0.593	20.71	0.425	28.13	0.620	10.60	0.151	24.85	0.243
T = 373.		6.62	0.577	20.85	0.398	28.28	0.645	10.89	0.148	25.03	0.224
		6.86	0.530	21.05	0.391	28.42	0.651	11.64	0.151	25.29	0.198
3.80	0.945	7.02	0.500	21.30	0.398	28.63	0.644	12.14	0.158	25.58	0.187
3.87	0.918	7.33	0.448	21.66	0.441	28.98	0.541	12.55	0.154	25.58	0.169
3.99	0.905	7.67	0.402	21.90	0.477	29.13	0.545	13.79	0.157	25.88	0.164
4.15	0.913	7.78	0.391	22.24	0.486	29.13	0.575	14.20	0.137	26.06	0.149
4.28	0.913	7.99	0.402	22.60	0.544	29.22	0.581	14.47	0.137	26.24	0.115
4.41	0.888	8.69	0.501	22.70	0.553	29.38	0.706	15.08	0.162	26.62	0.122
4.54	0.888	9.48	0.599	22.98	0.547	29.46	0.716	15.44	0.174	26.76	0.146
4.63	0.895	9.66	0.611	23.39	0.590	29.60	0.722	15.83	0.174	26.83	0.197
4.68	0.906	10.12	0.611	23.54	0.590	29.76	0.716	16.55	0.162	26.95	0.214
5.05	0.901	10.47	0.618	23.65	0.583	30.00	0.677	17.46	0.141	27.01	0.236
5.36	0.926	10.60	0.618	23.65	0.569			17.91	0.152	27.16	0.224
5.83	0.920	10.85	0.618	23.83	0.565	CURVE 4		18.15	0.158	27.16	0.205
6.02	0.920	11.35	0.610	23.98	0.576	T = 373.		18.44	0.158	27.59	0.170
6.21	0.910	12.65	0.626	24.19	0.571			18.63	0.148	27.88	0.170
6.32	0.894	13.20	0.626	24.49	0.555	3.63	0.406	18.83	0.148	28.00	0.187
6.53	0.861	13.88	0.619	24.66	0.563	3.80	0.386	19.07	0.139	28.07	0.194
6.79	0.821	14.28	0.598	24.86	0.651	4.04	0.331	19.42	0.139	28.20	0.185
7.00	0.786	14.47	0.580	24.94	0.704	4.23	0.301	19.65	0.133	28.39	0.163
		14.71	0.570	25.08	0.715	4.49	0.287	19.93	0.133	28.50	0.167
CURVE 3		15.00	0.580	25.24	0.705	4.68	0.256	20.37	0.112	28.64	0.151
T = 373.		15.35	0.623	25.41	0.663	5.03	0.236	20.91	0.121	28.88	0.167
		15.85	0.654	25.60	0.646	5.27	0.219	21.17	0.117	28.88	0.145
3.84	0.807	16.15	0.654	25.60	0.626	5.50	0.182	21.64	0.135	29.01	0.142

TABLE 11-10. EXPERIMENTAL ANGULAR SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE	4(CONT.)	CURVE	5(CONT.)	CURVE	6(CONT.)	CURVE	7(CONT.)	CURVE	7(CONT.)	CURVE	7(CONT.)
29.18	0.173	10.26	0.790	8.01	0.395	4.11	0.774	15.88	0.581	25.35	0.427
29.32	0.173	10.42	0.815	8.18	0.385	4.23	0.788	16.37	0.581	25.66	0.401
29.46	0.235	10.60	0.829	8.60	0.427	4.43	0.769	16.67	0.571	25.87	0.405
29.57	0.247	10.99	0.845	8.88	0.467	4.62	0.747	17.27	0.530	25.95	0.399
29.73	0.229	11.34	0.855	8.93	0.539	4.97	0.724	17.59	0.522	25.95	0.380
29.73	0.213	11.54	0.855	9.34	0.633	4.97	0.704	18.10	0.571	26.18	0.365
30.00	0.199	12.28	0.836	10.22	0.748	5.09	0.688	18.21	0.585	26.26	0.355
		12.71	0.836	10.60	0.764	5.51	0.665	18.38	0.592	26.26	0.343
CURVE 5		13.40	0.859	11.23	0.806	5.51	0.651	18.59	0.577	26.42	0.343
T = 373.		14.09	0.868	11.46	0.803	5.66	0.639	18.97	0.569	26.50	0.384
		14.63	0.887	11.79	0.801	6.07	0.626	19.25	0.523	26.58	0.394
4.10	0.970	15.55	0.887	11.88	0.789	6.27	0.607	19.42	0.502	26.90	0.401
4.11	0.941	15.93	0.899	12.11	0.794	6.41	0.576	19.55	0.468	27.04	0.424
4.09	0.923	16.50	0.899	12.42	0.785	6.37	0.568	19.72	0.453	27.09	0.498
4.39	0.915	16.93	0.911	12.87	0.791	6.62	0.516	19.81	0.423	27.25	0.513
4.59	0.902	17.54	0.911	13.63	0.811	6.74	0.471	20.18	0.384	27.34	0.502
4.96	0.902	18.60	0.934	14.01	0.821	6.89	0.441	20.18	0.351	27.34	0.465
5.33	0.915	18.79	0.882	14.18	0.834	7.07	0.386	20.49	0.289	27.49	0.461
5.63	0.915	19.00	0.874	14.53	0.838	7.39	0.325	20.72	0.246	27.49	0.445
5.93	0.928			15.01	0.838	7.54	0.282	20.84	0.218	27.61	0.448
6.13	0.928	CURVE 6		15.45	0.850	7.58	0.248	21.10	0.193	27.69	0.447
6.32	0.912	T = 373.		16.09	0.862	7.94	0.218	21.34	0.193	27.73	0.470
6.45	0.898			16.61	0.871	8.24	0.224	21.57	0.214	27.81	0.475
6.71	0.838	3.93	0.944	17.28	0.876	8.39	0.244	21.69	0.234	27.81	0.451
6.93	0.778	4.13	0.940	17.46	0.869	8.94	0.331	22.01	0.245	28.06	0.445
7.24	0.692	4.22	0.930	17.59	0.869	9.25	0.387	22.40	0.285	28.14	0.372
7.65	0.536	4.21	0.901	18.09	0.888	9.81	0.447	22.62	0.307	28.17	0.436
7.84	0.501	4.31	0.883	18.39	0.888	10.60	0.501	22.78	0.317	28.27	0.456
8.02	0.461	4.54	0.874	18.58	0.882	11.67	0.495	22.98	0.320	28.44	0.495
8.28	0.441	4.91	0.877	18.80	0.882	11.90	0.485	23.18	0.316	28.44	0.437
8.48	0.453	5.29	0.877	19.00	0.874	12.45	0.485	23.49	0.341	28.63	0.410
8.64	0.485	5.53	0.887			13.00	0.494	23.70	0.351	28.81	0.442
8.77	0.500	6.26	0.870	CURVE 7		13.28	0.500	24.16	0.355	28.90	0.469
8.91	0.504	6.51	0.820	T = 373.		13.95	0.504	24.35	0.373	28.92	0.512
8.91	0.538	7.13	0.638			14.26	0.492	24.52	0.395	29.10	0.487
9.33	0.632	7.28	0.600	3.72	0.770	14.48	0.487	24.67	0.401	29.38	0.558
9.41	0.678	7.28	0.561	3.80	0.750	14.77	0.487	24.89	0.391	29.46	0.638
9.56	0.712	7.55	0.501	3.80	0.734	15.10	0.521	25.19	0.438	29.46	0.524
9.97	0.760	7.60	0.472	3.96	0.774	15.41	0.544	25.27	0.443	29.62	0.465
10.07	0.781	7.84	0.426	3.98	0.767	15.60	0.571	25.35	0.437	29.69	0.491

TABLE 11-10. EXPERIMENTAL ANGULAR SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE	7(CONT.)	CURVE	8(CONT.)	CURVE	9(CONT.)	CURVE	9(CONT.)	CURVE	10(CONT.)	CURVE	10(CONT.)
30.80	0.519	13.31	0.914	5.44	0.912	19.55	0.875	9.83	0.578	21.90	0.418
		13.60	0.914	5.84	0.912	19.80	0.835	10.22	0.585	22.18	0.422
CURVE 8		13.94	0.924	6.15	0.906	20.00	0.812	10.60	0.585	22.35	0.450
T = 373.		14.10	0.916	6.36	0.887			11.07	0.591	22.53	0.470
		14.28	0.920	6.61	0.852	CURVE 10		11.40	0.584	22.87	0.481
3.86	0.956	14.79	0.918	6.92	0.794	T = 373.		11.58	0.580	23.26	0.488
3.98	0.962	15.04	0.926	7.11	0.741			11.95	0.580	23.52	0.500
4.21	0.962	15.39	0.930	7.45	0.661	3.47	0.848	12.41	0.587	23.84	0.494
4.34	0.950	15.52	0.926	7.60	0.623	3.57	0.832	12.87	0.584	24.03	0.505
4.61	0.946	15.95	0.936	7.67	0.592	3.62	0.800	13.22	0.589	24.19	0.523
4.86	0.934	16.31	0.936	7.81	0.569	3.75	0.789	13.55	0.594	24.46	0.524
5.06	0.928	16.58	0.940	8.03	0.547	3.80	0.789	14.20	0.558	24.66	0.537
5.26	0.938	16.71	0.940	8.21	0.547	3.97	0.792	14.37	0.550	24.78	0.561
5.48	0.924	16.89	0.942	8.60	0.563	4.05	0.786	15.01	0.583	25.02	0.580
5.60	0.936	17.12	0.938	8.95	0.645	4.05	0.771	15.24	0.599	25.13	0.610
6.05	0.936	17.49	0.945	9.08	0.682	4.24	0.763	15.33	0.608	25.22	0.616
6.22	0.940	17.76	0.942	9.48	0.782	4.47	0.763	15.59	0.622	25.34	0.611
6.71	0.922	18.05	0.942	9.80	0.826	4.99	0.739	15.73	0.631	25.46	0.570
6.91	0.896	18.46	0.949	10.07	0.853	5.28	0.708	16.00	0.631	25.87	0.562
7.29	0.808	18.70	0.949	10.60	0.871	5.53	0.684	16.16	0.628	26.05	0.535
7.60	0.713	18.93	0.945	10.95	0.881	5.65	0.654	16.54	0.617	26.27	0.503
7.60	0.686	19.12	0.933	11.22	0.881	5.83	0.643	16.80	0.585	26.38	0.490
7.94	0.593	19.34	0.914	11.77	0.890	6.12	0.638	17.28	0.561	26.58	0.469
7.94	0.585	19.51	0.897	12.12	0.880	6.25	0.625	17.76	0.592	26.73	0.485
8.29	0.556	20.00	0.842	12.36	0.875	6.31	0.597	18.04	0.612	26.80	0.499
8.42	0.564			12.64	0.875	6.52	0.572	18.47	0.612	27.02	0.572
8.73	0.630	CURVE 9		13.12	0.885	6.74	0.506	18.89	0.596	27.08	0.610
9.08	0.682	T = 373.		13.44	0.893	6.99	0.451	19.30	0.572	27.16	0.620
9.48	0.782			13.71	0.893	7.28	0.398	19.61	0.547	27.25	0.616
9.80	0.826	3.54	0.929	14.05	0.889	7.57	0.368	19.96	0.512	27.41	0.560
10.21	0.871	3.54	0.913	14.45	0.896	7.69	0.345	19.96	0.478	27.65	0.529
10.47	0.886	3.62	0.892	14.93	0.897	7.94	0.345	20.22	0.461	27.97	0.549
10.60	0.889	3.74	0.892	15.33	0.907	8.14	0.381	20.31	0.431	28.25	0.573
10.95	0.904	3.80	0.901	16.20	0.906	8.57	0.427	20.44	0.415	28.52	0.578
11.28	0.915	4.02	0.911	16.73	0.920	8.57	0.448	20.44	0.362	28.85	0.539
11.98	0.915	4.06	0.900	17.55	0.916	8.78	0.473	20.68	0.339	28.85	0.522
12.13	0.908	4.17	0.895	18.00	0.916	8.98	0.505	20.90	0.323	28.96	0.519
12.32	0.895	4.31	0.913	18.81	0.925	9.07	0.524	21.22	0.323	29.17	0.545
12.61	0.895	5.00	0.933	19.02	0.917	9.31	0.548	21.54	0.360	29.36	0.559
13.08	0.904	5.20	0.918	19.25	0.909	9.77	0.565	21.72	0.376	29.57	0.548

TABLE 11-10. EXPERIMENTAL ANGULAR SPECTRAL EMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 10(CONT.)	
29.73	0.557
30.00	0.556
CURVE 11	
T = 373.	
3.67	0.295
3.80	0.284
4.09	0.252
4.24	0.228
4.44	0.211
4.70	0.203
4.81	0.184
5.12	0.176
5.25	0.159
5.52	0.147
5.82	0.130
6.21	0.126
6.44	0.109
6.80	0.085
7.07	0.077
7.41	0.077
8.08	0.097
8.94	0.118
9.39	0.118
10.19	0.114
10.60	0.114
13.93	0.114
14.13	0.106
14.69	0.103
14.99	0.121
15.57	0.130
15.87	0.130
16.89	0.106
17.47	0.106
17.74	0.118
18.02	0.118
18.39	0.108
18.59	0.103
18.82	0.114

λ	ε
CURVE 11(CONT.)	
19.22	0.099
19.45	0.099
19.97	0.083
20.47	0.073
20.75	0.073
21.15	0.073
21.42	0.080
21.55	0.097
22.33	0.097
22.94	0.106
23.52	0.101
23.96	0.101
24.14	0.104
24.28	0.111
24.54	0.111
24.64	0.129
24.75	0.146
24.95	0.146
25.61	0.112
25.88	0.114
26.00	0.109
26.00	0.095
26.26	0.086
26.45	0.093
26.56	0.109
27.07	0.133
27.24	0.133
27.55	0.105
27.87	0.121
28.21	0.121
28.47	0.112
28.47	0.102
28.67	0.080
28.83	0.080
28.91	0.106
29.00	0.133
29.34	0.152
29.43	0.143
29.43	0.125
29.58	0.121

λ	ε
CURVE 11(CONT.)	
30.00	0.133

c. Normal Spectral Reflectance (Wavelength Dependence)

A total of 16 sets of experimental data were located for the wavelength dependence of the normal spectral reflectance of vitreous silica. The data are listed in Table 11-13 and shown in Figures 11-7 and 11-8. Specimen characterization and measurement information for the data are given in Table 11-12. Calculations were carried out using the Fresnel equations for specular reflection, Eqs. (2.4-1), (2.4-2), and (2.4-5). These calculations appear as curves 17 to 25 in Tables 11-12 and 11-13 and in Figures 11-7 and 11-8.

The data above 7 μm shows a general trend. It rises sharply above 7.4 μm to a peak at about 9 μm and then decreases to about 0.1 at 12 μm. All the data is for room temperature, with the exception of Gaskell's [T39543] which were measured at up to 1173 K.

Provisional values are listed in Table 11-11 and shown in Figure 11-7. One curve is based on calculations using the Fresnel equations and is valid with the context of an optically smooth specimen, a temperature of 293 K, unpolarized radiation, a wavelength range of 7 to 16.0 μm, an angle of incidence, θ, of 0°, and a viewing angle, θ', of 0°. The calculated values and curve 16 differ by about 30% at 12.8 μm and, therefore, the uncertainty for these provisional values are within 30%. A provisional curve for 1173 K is also given with a wavelength range of validity between 7.7 and 14 μm. These values are also listed in Table 11-11 and shown in Figure 11-7. These values are based on curve 10 and an uncertainty of 30% is assigned because of the lack of confirmatory data.

TABLE 11-11. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF SILICA (VITREOUS) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ
OPTICALLY SMOOTH		OPTICALLY SMOOTH			
T = 293		T = 293 (CONT.)		T = 1173	
7.00	0.001	10.4	0.145	7.65	0.000
7.10	0.000	10.6	0.113	7.83	0.009
7.20	0.000	10.8	0.111	7.95	0.037
7.30	0.000	11.0	0.103	8.0	0.057
7.40	0.000	11.2	0.098	8.19	0.099
7.50	0.001	11.4	0.091	8.31	0.218
7.60	0.003	11.6	0.085	8.63	0.309
7.70	0.010	11.8	0.077	8.74	0.345
7.80	0.020	12.0	0.077	9.0	0.475
7.90	0.051	12.2	0.083	9.06	0.505
8.00	0.135	12.4	0.097	9.16	0.518
8.10	0.268	12.6	0.106	9.25	0.497
8.20	0.314	12.8	0.119	9.59	0.368
8.30	0.305	13.0	0.110	9.88	0.278
8.40	0.336	13.2	0.102	10.0	0.247
8.50	0.368	13.4	0.097	10.1	0.220
8.60	0.422	13.6	0.089	10.5	0.160
8.65	0.461	13.8	0.081	10.9	0.120
8.70	0.521	14.0	0.077	11.0	0.116
8.75	0.567	14.2	0.072	11.5	0.087
8.80	0.632	14.4	0.143	11.9	0.078
8.85	0.679	14.6	0.065	12.0	0.077
8.90	0.702	16.0	0.039	12.2	0.078
8.95	0.719			12.7	0.088
9.00	0.670			13.0	0.088
9.05	0.618			13.3	0.079
9.10	0.465			13.5	0.078
9.15	0.530				
9.20	0.474				
9.30	0.453				
9.35	0.416				
9.40	0.311				
9.50	0.343				
9.60	0.313				
9.70	0.294				
9.80	0.252				
9.90	0.229				
10.0	0.205				
10.2	0.166				

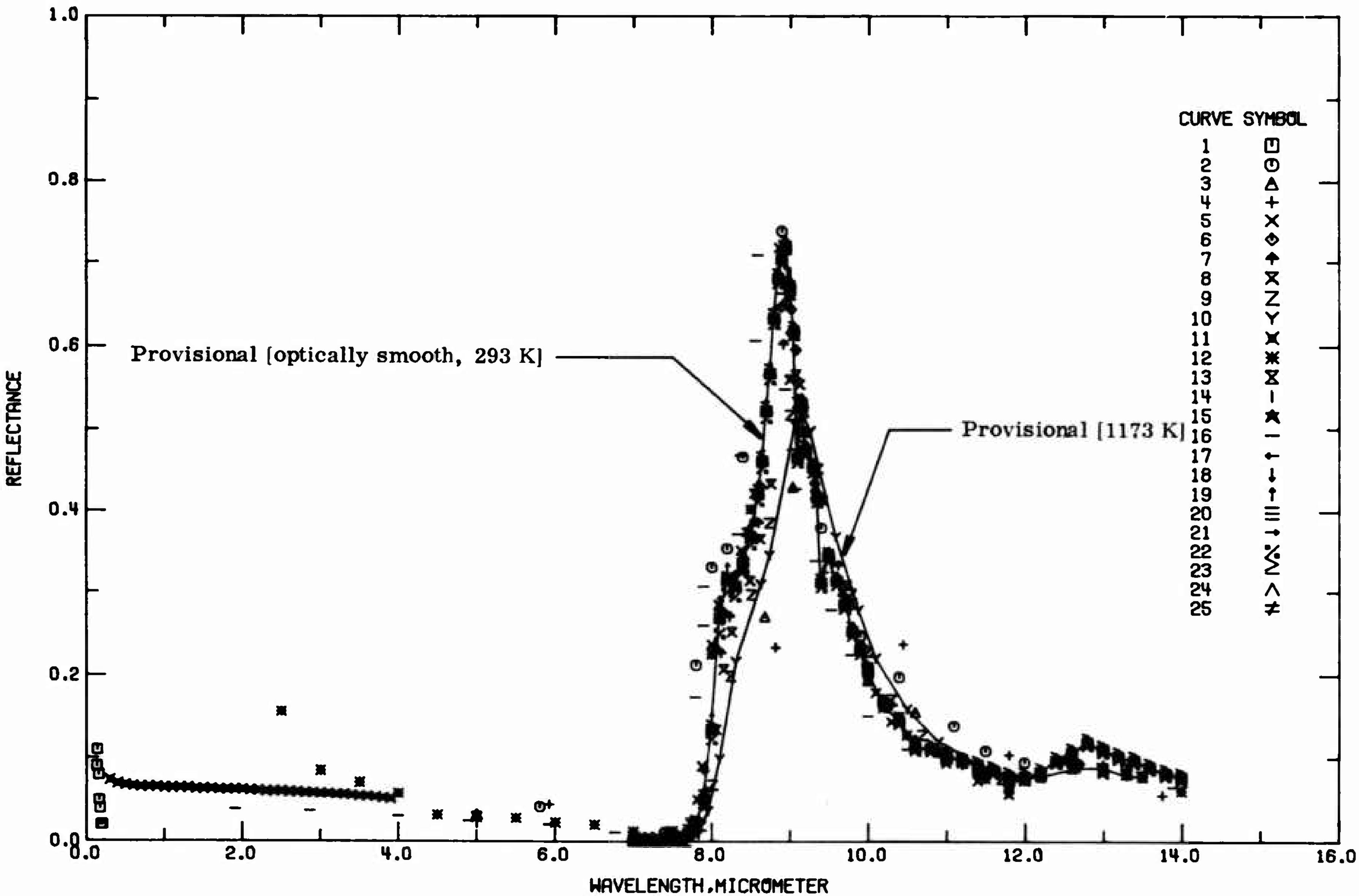


FIGURE 11-7. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

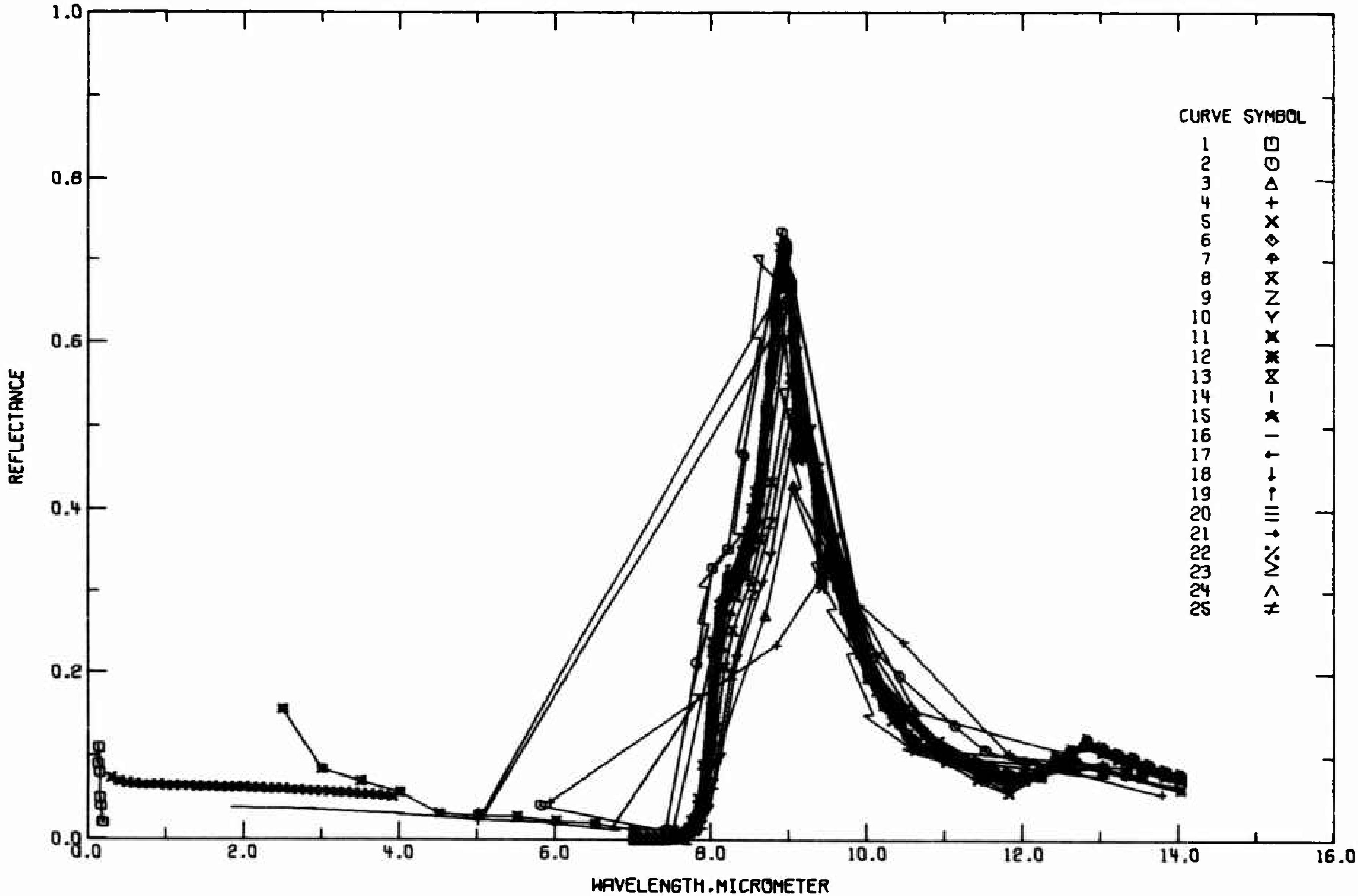


FIGURE 11-8. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

TABLE 11-12. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF SILICA (VITREOUS) (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T31731	Johnson, B.K.	1941	0.13-0.20	293	Fused quartz	Reflecting surface polished, back surface ground to prevent reflection from it; measured in vacuum (0.001 mm Hg); measurement temperature not given explicitly, assumed to be 293 K; data reported called reflection coefficient; $\theta \sim 0°$, $\theta' \sim 0°$.
2	T40528	Sulzbach, F. and Turner, A.F.	1966	5.8-38	293	Fused quartz	Measurement temperature specified as room temperature, 293 K assigned; data extracted from smooth curve; Perkin Elmer models 21 and 221 spectrophotometers used for reflectance measurements; $\theta \sim 0°$.
3	T40528	Sulzbach, F. and Turner, A.F.	1966	7.7-38	293		Clear film; electrom beam deposited at normal incidence on glass at 588 K at 2 to 8×10^{-5} mm Hg; rate of deposit one quarterwave min^{-1} at $\lambda = 0.5$ μm; optical film thickness, i.e., index of refraction times thickness equals 10 $\lambda/4$ at 2.5 μ; measurement temperature specified as room temperature, 293 K assigned; data from figure; Perkin Elmer models 21 and 221 spectrophotometers used for reflectance measurements; $\theta \sim 0°$.
4	T40528	Sulzbach, F. and Turner, A.F.	1966	5.9-34	293		Unfilmed glass substrate; measurement temperature specified as room temperature, 293 K assigned; data from figure; Perkin Elmer models 21 and 221 spectrophotometers used for reflectance measurement; $\theta \sim 0°$.
5	T39543	Gaskell, P.H.	1965	7.5-14	293	Vitreous silica	Plate specimen; author reports reflectivity; Perkin Elmer 12c spectrometer used; smooth values from figure; $\theta \sim 7°$, $\theta' \sim 7°$.
6	T39543	Gaskell, P.H.	1965	7.5-14	480	Vitreous silica	Similar to the above specimen.
7	T39543	Gaskell, P.H.	1965	7.5-14	636	Vitreous silica	Similar to the above specimen.
8	T39543	Gaskell, P.H.	1965	7.6-14	796	Vitreous silica	Similar to the above specimen.
9	T39543	Gaskell, P.H.	1965	7.7-14	1035	Vitreous silica	Similar to the above specimen.
10	T39543	Gaskell, P.H.	1965	7.7-14	1173	Vitreous silica	Similar to the above specimen.
11	E62600, E21758			0.30-3.9	293	Fused silica	Normal spectral reflectance calculated from $(n-1)^2/(n^2+1)$ (for polished, uncoated, plane-parallel plate, considering multiple internal reflections, and assuming zero absorption) where refractive index n was calculated using $n^2-1 = 0.6961663\ \lambda^2/(\lambda^2-(0.0684043)^2) + 0.4079426\ \lambda^2/(\lambda^2-(0.1162414)^2) + 0.8974794\ \lambda^2/(\lambda^2-(9.896161)^2)$ with wavelength λ in microns [E21758]; $\theta = 0°$, $\theta' = 0°$.
12	T76947	General Dynamics Convair Aerospace Division	1974	2.5-24	293	Optosil 1	Specimen thickness 0.125 in.; polished disk; specimen provided by Aerospace Corp. who obtained it from Amersil, Inc., Hillside, New Jersey; measurements made using the General Dynamics Convair Aerospace ellipsoidal reflectometer and a Perkin Elmer Model 210 monochromator for dispersion; data gathered without use of polarizers; reflectance obtained by comparison of reflected energy from specimen with that reflected by Convair vacuum-deposited gold sample; data gathered at atmospheric pressure; measurement temperature specified as room temperature, 293 K assigned; five readings taken of the gold standard and five of the specimen, average values used in determination of reflectance; $\theta = 12°$, $\theta' = 12°$.
13	T76947	General Dynamics Convair Aerospace Division	1974	10-22	293	Optosil 1, Convair Sample F	Specimen thickness 0.125 in.; polished disk; specimen provided by Aerospace Corp. who obtained it from Amersil, Inc., Hillside, New Jersey; measurements made using the General Dynamics Convair Aerospace ellipsoidal reflectometer and a Perkin Elmer Model 210 monochromator for dispersion and Advanced Ballistic Missile Defense Agency wire grid polarizers which were mounted as close as possible to the thermocouple detector; data gathered at atmospheric pressure; measurement temperature specified as room temperature, 293 K assigned; absolute reflectance determined directly; reflectance values reported are for component parallel to plane of incidence; five readings taken and average used in determining reflectance; data from figure; $\theta = 12°$, $\theta' = 12°$.

TABLE 11-12. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, µm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
14	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen except reflectance values reported are for component perpendicular to the plane of incidence.
15	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen except reflectance values reported are for average of the two polarized components.
16	T30490	Howarth, L.E. and Spitzer, W.G.	1961	1.9-29	293	Vitreous silica	Reflectivity measured by comparison with front surface aluminum mirror; Perkin Elmer single-beam double pass spectrometer used; measurement temperature not given explicitly, assumed to be 293 K; $\theta \sim 0°$, $\theta' \sim 0°$.
17	A00012		1975	7.0-16	293		Calculations for fused silica performed for a homogeneous, smooth surface and for perpendicular component (eq. 2.4-1) of incident radiation; data for index of refraction, n, and absorption index, k, from [A00012]; $\theta = 0°$, $\theta' = 0°$.
18	A00012		1975	7.0-16	293		Similar to the above specimen except $\theta = 5°$, $\theta' = 5°$.
19	A00012		1975	7.0-16	293		Similar to the above specimen except $\theta = 10°$, $\theta' = 10°$.
20	A00012		1975	7.0-16	293		Similar to the above specimen except for parallel component (eq. 2.4-2) of incident radiation and $\theta = 0°$, $\theta' = 0°$.
21	A00012		1975	7.0-16	293		Similar to the above specimen except $\theta = 5°$, $\theta' = 5°$.
22	A00012		1975	7.0-16	293		Similar to the above specimen except $\theta = 10°$, $\theta' = 10°$.
23	A00012		1975	7.0-16	293		Similar to the above specimen except for unpolarized radiation (eq. 2.4-5) and $\theta = 0°$, $\theta' = 0°$.
24	A00012		1975	7.0-16	293		Similar to the above specimen except for $\theta = 5°$, $\theta' = 5°$.
25	A00012		1975	7.0-16	293		Similar to the above specimen except for $\theta = 10°$, $\theta' = 10°$.

TABLE 11-13. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 293.	
0.1347	0.09
0.1438	0.11
0.1570	0.08
0.1640	0.05
0.1757	0.04
0.1901	0.02
0.2026	0.02
CURVE 2	
T = 293.	
5.80	0.042
7.40	0.011
7.80	0.212
8.00	0.330
8.20	0.353
8.40	0.466
8.90	0.736
9.20	0.473
9.40	0.379
9.80	0.285
9.90	0.247
10.4	0.198
11.1	0.139
11.5	0.109
12.8	0.095
13.3	0.088
15.7	0.056
18.0	0.010
18.8	0.012
19.3	0.042
19.7	0.145
20.4	0.468
20.7	0.555
21.2	0.533
21.6	0.490
21.8	0.440
22.1	0.390
22.8	0.306
CURVE 2 (CONT.)	
23.6	0.293
24.2	0.273
24.7	0.235
25.0	0.225
25.7	0.208
26.5	0.197
27.5	0.186
28.8	0.178
32.0	0.171
34.4	0.157
36.2	0.150
38.0	0.145
CURVE 3	
T = 293.	
7.73	0.012
8.68	0.270
9.04	0.430
10.60	0.156
12.56	0.105
19.79	0.022
21.35	0.163
23.84	0.179
26.26	0.142
29.89	0.122
33.80	0.122
38.00	0.120
CURVE 4	
T = 293.	
5.92	0.045
8.82	0.233
9.43	0.324
10.45	0.237
11.80	0.104
13.76	0.056
17.95	0.014
18.37	0.072
CURVE 4 (CONT.)	
14.81	0.056
19.73	0.152
20.76	0.235
21.27	0.248
21.75	0.239
33.50	0.100
CURVE 5	
T = 293.	
7.51	0.005
7.73	0.023
7.82	0.051
7.88	0.090
8.00	0.237
8.09	0.284
8.20	0.318
8.38	0.351
8.45	0.374
8.55	0.422
8.87	0.716
8.92	0.720
8.95	0.716
9.19	0.496
9.33	0.420
9.68	0.301
9.89	0.230
10.1	0.179
10.3	0.144
10.6	0.119
11.0	0.094
11.4	0.073
11.8	0.057
12.2	0.078
12.6	0.095
13.0	0.088
13.3	0.080
13.5	0.078
CURVE 6	
T = 480.	
7.49	0.003
7.76	0.026
7.91	0.085
8.06	0.232
8.15	0.275
8.42	0.341
8.55	0.387
8.62	0.431
8.89	0.646
8.96	0.652
9.02	0.643
9.08	0.595
9.32	0.434
9.73	0.284
9.98	0.212
10.2	0.162
10.6	0.122
11.4	0.078
11.8	0.060
12.2	0.078
12.7	0.094
13.0	0.088
13.3	0.081
13.5	0.078
CURVE 7	
T = 636.	
7.56	0.000
7.82	0.026
7.92	0.061
8.12	0.226
8.23	0.270
8.42	0.324
8.60	0.385
8.92	0.602
9.01	0.615
9.07	0.595
9.21	0.495
CURVE 7 (CONT.)	
9.36	0.420
9.62	0.333
9.93	0.234
10.3	0.164
10.9	0.107
11.2	0.091
11.8	0.065
12.2	0.078
12.6	0.091
13.0	0.088
13.3	0.081
13.5	0.078
CURVE 8	
T = 796.	
7.64	0.000
7.92	0.043
8.06	0.134
8.16	0.207
8.26	0.251
8.49	0.313
8.62	0.365
8.76	0.433
9.00	0.559
9.08	0.565
9.13	0.553
9.42	0.413
9.73	0.307
10.0	0.209
10.4	0.150
11.8	0.073
12.2	0.078
12.6	0.089
13.0	0.088
13.3	0.081
13.5	0.078
CURVE 9	
T = 1035.	
7.67	0.000
7.86	0.019
8.01	0.068
8.24	0.199
8.51	0.296
8.74	0.385
9.01	0.516
9.10	0.531
9.17	0.520
9.36	0.452
9.79	0.297
10.0	0.228
10.3	0.171
10.7	0.128
11.2	0.099
11.7	0.075
12.2	0.078
12.6	0.088
13.0	0.088
13.3	0.081
13.5	0.078
CURVE 10	
T = 1173.	
7.66	0.000
7.83	0.009
7.95	0.037
8.10	0.099
8.31	0.216
8.63	0.309
8.74	0.345
9.06	0.505
9.16	0.518
9.26	0.497
9.59	0.368
9.88	0.278
10.1	0.220
10.5	0.160

TABLE 11-13. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 10 (CONT.)	
10.9	0.120
11.5	0.087
11.9	0.078
12.2	0.078
12.7	0.088
13.0	0.088
13.3	0.0788
13.5	0.078
CURVE 11	
T = 293.	
0.30	0.074
0.40	0.070
0.50	0.068
0.60	0.067
0.70	0.066
0.80	0.066
0.90	0.066
1.00	0.065
1.10	0.065
1.20	0.065
1.30	0.065
1.40	0.064
1.50	0.064
1.60	0.064
1.70	0.063
1.80	0.063
1.90	0.063
2.00	0.063
2.10	0.062
2.20	0.062
2.30	0.061
2.40	0.061
2.50	0.061
2.60	0.060
2.70	0.060
2.80	0.059
2.90	0.059
3.00	0.058
CURVE 11 (CONT.)	
3.10	0.058
3.20	0.057
3.30	0.057
3.40	0.056
3.50	0.055
3.60	0.055
3.70	0.054
3.80	0.053
3.90	0.052
CURVE 12	
T = 293.	
2.5	0.156
3.0	0.085
3.5	0.071
4.0	0.058
4.5	0.032
5.0	0.029
5.5	0.028
6.0	0.023
6.5	0.020
7.0	0.012
7.5	0.013
8.0	0.225
8.5	0.402
9.0	0.667
9.5	0.347
10.0	0.195
10.5	0.128
11.0	0.100
11.5	0.075
12.0	0.073
12.5	0.098
13.0	0.086
14.0	0.061
15.0	0.049
16.0	0.044
17.0	0.036
18.0	0.032
CURVE 12 (CONT.)	
19.0	0.031
20.0	0.257
21.0	0.553
22.0	0.386
23.0	0.286
24.0	0.227
CURVE 13	
T = 293.	
10.0	0.194
11.0	0.099
13.0	0.086
16.0	0.044
22.0	0.384
CURVE 14	
T = 293.	
5.0	0.022
9.0	0.687
10.0	0.210
11.0	0.108
13.0	0.092
16.0	0.049
22.0	0.398
CURVE 15	
T = 293.	
5.0	0.033
9.0	0.660
10.0	0.204
11.0	0.104
13.0	0.082
16.0	0.051
22.0	0.394
CURVE 16	
T = 293.	
1.90	0.039
2.86	0.037
3.99	0.031
4.89	0.025
5.92	0.021
6.76	0.011
7.73	0.174
7.89	0.259
7.89	0.306
8.33	0.371
8.37	0.468
8.56	0.606
8.59	0.707
8.91	0.662
8.94	0.547
9.04	0.475
9.08	0.427
9.33	0.338
9.53	0.278
9.78	0.224
10.0	0.151
10.5	0.111
11.4	0.081
12.2	0.081
12.9	0.088
13.9	0.065
14.9	0.055
16.0	0.047
16.9	0.035
17.9	0.025
17.9	0.039
18.9	0.031
19.3	0.075
19.6	0.146
19.9	0.280
20.2	0.406
20.3	0.503
20.7	0.554
21.2	0.508
CURVE 16 (CONT.)	
21.4	0.475
21.9	0.405
23.5	0.264
23.9	0.236
24.4	0.222
25.9	0.191
27.0	0.175
28.0	0.169
28.4	0.158
29.0	0.161
CURVE 17	
T = 293.	
7.00	0.0006
7.10	0.0004
7.20	0.0001
7.30	0.0001
7.40	0.0005
7.50	0.0015
7.60	0.0031
7.70	0.0096
7.80	0.0204
7.90	0.0511
8.00	0.1351
8.10	0.2681
8.20	0.3137
8.30	0.3064
8.40	0.3360
8.50	0.3682
8.60	0.4216
8.65	0.4613
8.70	0.5207
8.75	0.5666
8.80	0.6325
8.85	0.6794
8.90	0.7018
8.95	0.7187
9.00	0.6764
9.05	0.6176
CURVE 17 (CONT.)	
9.10	0.4649
9.15	0.5301
9.20	0.4744
9.30	0.4527
9.35	0.4164
9.40	0.3106
9.50	0.3433
9.60	0.3129
9.70	0.2841
9.80	0.2521
9.90	0.2235
10.0	0.2050
10.2	0.1665
10.4	0.1452
10.6	0.1126
10.8	0.1114
11.0	0.1029
11.2	0.0977
11.4	0.0915
11.6	0.0848
11.8	0.0775
12.0	0.0771
12.2	0.0828
12.4	0.0966
12.6	0.1063
12.8	0.1186
13.0	0.1101
13.2	0.1018
13.4	0.0970
13.6	0.0887
13.8	0.0810
14.0	0.0766
14.2	0.0723
14.4	0.1433
14.6	0.0652
16.0	0.0398

TABLE 11-13. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 18	
T = 293.	
7.00	0.0006
7.10	0.0004
7.20	0.0002
7.30	0.0001
7.40	0.0005
7.50	0.0015
7.60	0.0032
7.70	0.0097
7.80	0.0208
7.90	0.0523
8.00	0.1385
8.10	0.2732
8.20	0.3176
8.30	0.3098
8.40	0.3389
8.50	0.3709
8.60	0.4240
8.65	0.4637
8.70	0.5228
8.75	0.5685
8.80	0.6341
8.85	0.6808
8.90	0.7031
8.95	0.7198
9.00	0.6716
9.05	0.6188
9.10	0.4664
9.15	0.5314
9.20	0.4758
9.30	0.4541
9.35	0.4178
9.40	0.3120
9.50	0.3447
9.60	0.3142
9.70	0.2854
9.80	0.2534
9.90	0.2308
10.0	0.2052
10.2	0.1676
CURVE 18(CONT.)	
10.4	0.1462
10.6	0.1134
10.8	0.1122
11.0	0.1037
11.2	0.0985
11.4	0.0923
11.6	0.0855
11.8	0.0782
12.0	0.0778
12.2	0.0835
12.4	0.0974
12.6	0.1072
12.8	0.1195
13.0	0.1109
13.2	0.1026
13.4	0.0977
13.6	0.0895
13.8	0.0817
14.0	0.0773
14.2	0.0729
14.4	0.1443
14.6	0.0658
16.0	0.0402
CURVE 19	
T = 293.	
7.00	0.0007
7.10	0.0005
7.20	0.0002
7.30	0.0001
7.40	0.0005
7.50	0.0016
7.60	0.0034
7.70	0.0103
7.80	0.0221
7.90	0.0561
8.00	0.1490
8.10	0.2888
8.20	0.3295
CURVE 19(CONT.)	
8.30	0.3200
8.40	0.3473
8.50	0.3788
8.60	0.4314
8.65	0.4705
8.70	0.5290
8.75	0.5741
8.80	0.6390
8.85	0.6850
8.90	0.7069
8.95	0.7231
9.00	0.6751
9.05	0.6225
9.10	0.4707
9.15	0.5355
9.20	0.4800
9.30	0.4584
9.35	0.4221
9.40	0.3162
9.50	0.3489
9.60	0.3184
9.70	0.2895
9.80	0.2572
9.90	0.2345
10.0	0.2098
10.2	0.1708
10.4	0.1492
10.6	0.1160
10.8	0.1148
11.0	0.1062
11.2	0.1008
11.4	0.0946
11.6	0.0877
11.8	0.0803
12.0	0.0799
12.2	0.0856
12.4	0.0998
12.6	0.1097
12.8	0.1222
13.0	0.1135
CURVE 19(CONT.)	
13.2	0.1050
13.4	0.1001
13.6	0.0917
13.8	0.0838
14.0	0.0793
14.2	0.0749
14.4	0.1475
14.6	0.0676
16.0	0.0414
CURVE 20	
T = 293.	
7.00	0.0006
7.10	0.0004
7.20	0.0001
7.30	0.0001
7.40	0.0005
7.50	0.0015
7.60	0.0031
7.70	0.0096
7.80	0.0204
7.90	0.0511
8.00	0.1351
8.10	0.2681
8.20	0.3137
8.30	0.3064
8.40	0.3360
8.50	0.3682
8.60	0.4216
8.65	0.4613
8.70	0.5207
8.75	0.5666
8.80	0.6325
8.85	0.6794
8.90	0.7018
8.95	0.7187
9.00	0.6704
9.05	0.6176
9.10	0.4649
CURVE 20(CONT.)	
9.15	0.5301
9.20	0.4744
9.30	0.4527
9.35	0.4164
9.40	0.3106
9.50	0.3433
9.60	0.3129
9.70	0.2841
9.80	0.2521
9.90	0.2295
10.0	0.2050
10.2	0.1665
10.4	0.1452
10.6	0.1126
10.8	0.1114
11.0	0.1029
11.2	0.0977
11.4	0.0915
11.6	0.0848
11.8	0.0775
12.0	0.0771
12.2	0.0828
12.4	0.0966
12.6	0.1063
12.8	0.1186
13.0	0.1101
13.2	0.1018
13.4	0.0970
13.6	0.0887
13.8	0.0810
14.0	0.0766
14.2	0.0723
14.4	0.1433
14.6	0.0652
16.0	0.0398
CURVE 21	
T = 293.	
7.00	0.0006
CURVE 21(CONT.)	
7.10	0.0004
7.20	0.0001
7.30	0.0001
7.40	0.0005
7.50	0.0015
7.60	0.0031
7.70	0.0094
7.80	0.0200
7.90	0.0506
8.00	0.1319
8.10	0.2630
8.20	0.3098
8.30	0.3030
8.40	0.3332
8.50	0.3656
8.60	0.4191
8.65	0.4591
8.70	0.5186
8.75	0.5647
8.80	0.6308
8.85	0.6780
8.90	0.7006
8.95	0.7176
9.00	0.6693
9.05	0.6163
9.10	0.4635
9.15	0.5287
9.20	0.4730
9.30	0.4513
9.35	0.4149
9.40	0.3092
9.50	0.3419
9.60	0.3115
9.70	0.2828
9.80	0.2508
9.90	0.2283
10.0	0.2039
10.2	0.1654
10.4	0.1442
10.6	0.1117

TABLE 11-13. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
CURVE 21(CONT.)		CURVE 22(CONT.)		CURVE 22(CONT.)		CURVE 23(CONT.)		CURVE 24(CONT.)		CURVE 24(CONT.)	
10.8	0.1105	8.50	0.3581	13.6	0.0858	9.30	0.4527	7.30	0.0001	11.2	0.0977
11.0	0.1021	8.60	0.4122	13.8	0.0782	9.35	0.4164	7.40	0.0005	11.4	0.0915
11.2	0.0969	8.65	0.4525	14.0	0.0739	9.40	0.3106	7.50	0.0015	11.6	0.0848
11.4	0.0938	8.70	0.5126	14.2	0.0698	9.50	0.3433	7.60	0.0031	11.8	0.0775
11.6	0.0841	8.75	0.5592	14.4	0.1391	9.60	0.3129	7.70	0.0096	12.0	0.0771
11.8	0.0769	8.80	0.6260	14.6	0.0628	9.70	0.2841	7.80	0.0204	12.2	0.0828
12.0	0.0765	8.85	0.6739	16.0	0.0382	9.80	0.2521	7.90	0.0511	12.4	0.0966
12.2	0.0821	8.90	0.6968			9.90	0.2295	8.00	0.1352	12.6	0.1063
12.4	0.0958	8.95	0.7144	CURVE 23		10.0	0.2050	8.10	0.2681	12.8	0.1186
12.6	0.1055	9.00	0.6658	T = 293.		10.2	0.1665	8.20	0.3137	13.0	0.1101
12.8	0.1177	9.05	0.6126			10.4	0.1452	8.30	0.3064	13.2	0.1018
13.0	0.1093	9.10	0.4591	7.00	0.0006	10.6	0.1126	8.40	0.3360	13.4	0.0970
13.2	0.1010	9.15	0.5247	7.10	0.0004	10.8	0.1114	8.50	0.3682	13.6	0.0887
13.4	0.0962	9.20	0.4683	7.20	0.0001	11.0	0.1029	8.60	0.4216	13.8	0.0810
13.6	0.0880	9.30	0.4471	7.30	0.0001	11.2	0.0977	8.65	0.4614	14.0	0.0766
13.8	0.0803	9.35	0.4106	7.40	0.0005	11.4	0.0915	8.70	0.5207	14.2	0.0723
14.0	0.0759	9.40	0.3051	7.50	0.0015	11.6	0.0848	8.75	0.5666	14.4	0.1433
14.2	0.0717	9.50	0.3377	7.60	0.0031	11.8	0.0775	8.80	0.6325	14.6	0.0652
14.4	0.1423	9.60	0.3074	7.70	0.0096	12.0	0.0771	8.85	0.6794	16.0	0.0398
14.6	0.0646	9.70	0.2788	7.80	0.0204	12.2	0.0828	8.90	0.7018		
16.0	0.0394	9.80	0.2469	7.90	0.0511	12.4	0.0966	8.95	0.7187	CURVE 25	
		9.90	0.2246	8.00	0.1351	12.6	0.1063	9.00	0.6704	T = 293.	
CURVE 22		10.0	0.2063	8.10	0.2681	12.8	0.1186	9.05	0.6176		
T = 293.		10.2	0.1622	8.20	0.3137	13.0	0.1101	9.10	0.4649	7.00	0.0006
		10.4	0.1412	8.30	0.3064	13.2	0.1018	9.15	0.5301	7.10	0.0004
7.00	0.0006	10.6	0.1091	8.40	0.3360	13.4	0.0970	9.20	0.4744	7.20	0.0001
7.10	0.0004	10.8	0.1080	8.50	0.3682	13.6	0.0887	9.30	0.4527	7.30	0.0001
7.20	0.0001	11.0	0.0996	8.60	0.4216	13.8	0.0810	9.35	0.4164	7.40	0.0005
7.30	0.0031	11.2	0.0945	8.65	0.4613	14.0	0.0766	9.40	0.3106	7.50	0.0015
7.40	0.0005	11.4	0.0885	8.70	0.5207	14.2	0.0723	9.50	0.3433	7.60	0.0031
7.50	0.0014	11.6	0.0819	8.75	0.5666	14.4	0.1433	9.60	0.3129	7.70	0.0096
7.60	0.0029	11.8	0.0749	8.80	0.6325	14.6	0.0652	9.70	0.2841	7.80	0.0204
7.70	0.0089	12.0	0.0744	8.85	0.6794	16.0	0.0398	9.80	0.2521	7.90	0.0512
7.80	0.0187	12.2	0.0799	8.90	0.7018			9.90	0.2295	8.00	0.1357
7.90	0.0464	12.4	0.0934	8.95	0.7187	CURVE 24		10.0	0.2050	8.10	0.2693
8.00	0.1223	12.6	0.1030	9.00	0.6704	T = 293.		10.2	0.1665	8.20	0.3144
8.10	0.2497	12.8	0.1151	9.05	0.6176			10.4	0.1452	8.30	0.3069
8.20	0.2992	13.0	0.1067	9.10	0.4649	7.00	0.0006	10.6	0.1126	8.40	0.3363
8.30	0.2938	13.2	0.0986	9.15	0.5301	7.10	0.0004	10.8	0.1114	8.50	0.3684
8.40	0.3253	13.4	0.0938	9.20	0.4744	7.20	0.0001	11.0	0.1029	8.60	0.4218

TABLE 11-13. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ
CURVE 25(CONT.)		CURVE 25(CONT.)	
8.65	0.4615	14.0	0.0766
8.70	0.5208	14.2	0.0723
8.75	0.5666	14.4	0.1433
8.80	0.6325	14.6	0.0652
8.85	0.6734	16.0	0.0399
8.90	0.7018		
8.95	0.7187		
9.00	0.6704		
9.05	0.6175		
9.10	0.4649		
9.15	0.5331		
9.20	0.4744		
9.30	0.4527		
9.35	0.4164		
9.40	0.3106		
9.50	0.3433		
9.60	0.3129		
9.70	0.2841		
9.80	0.2521		
9.90	0.2296		
10.0	0.2051		
10.2	0.1665		
10.4	0.1452		
10.6	0.1126		
10.8	0.1114		
11.0	0.1029		
11.2	0.0977		
11.4	0.0916		
11.6	0.0848		
11.8	0.0776		
12.0	0.0772		
12.2	0.0828		
12.4	0.0956		
12.6	0.1064		
12.8	0.1187		
13.0	0.1101		
13.2	0.1018		
13.4	0.0970		
13.6	0.0887		
13.8	0.0810		

d. Normal Spectral Reflectance (Temperature Dependence)

No experimental data sets were found for the temperature dependence of the normal spectral reflectance of vitreous silica. However, a provisional curve was generated for 10.6 μm from curves 5-10 of Tables 11-12 and 11-13 together with the provisional values at 293 K for the wavelength dependence of the normal spectral reflectance. The values are listed in Table 11-14 and shown in Figure 11-9. An uncertainty of within 30% is assigned. It is noted that from 293 to 1173 K, there is an increase in the normal spectral reflectance.

TABLE 11-14. PROVSIONAL NORMAL SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

T	ρ
λ = 10.6	
293.	0.113
480.	0.122
636.	0.134
796.	0.138
1035.	0.138
1173.	0.150

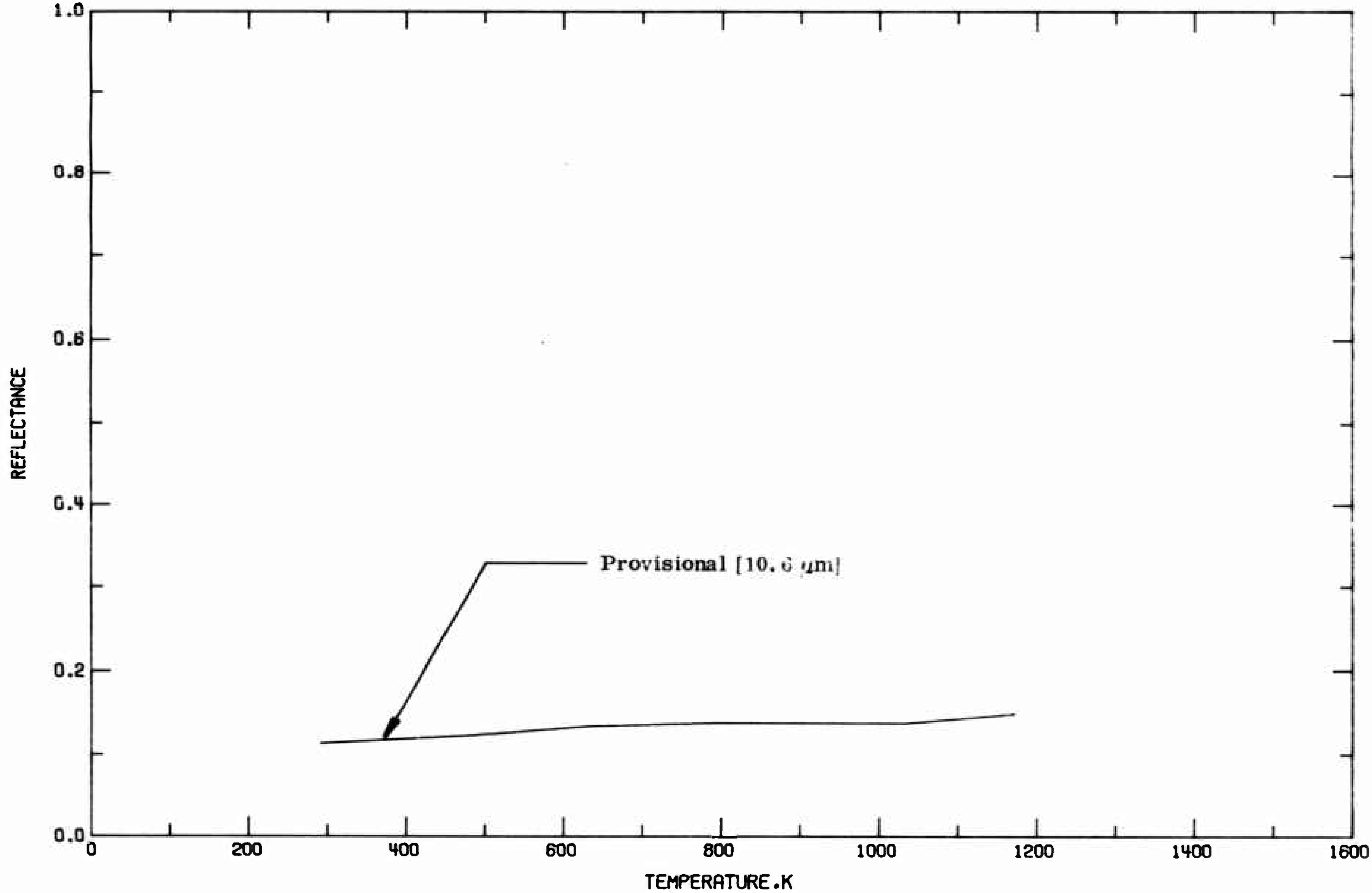


FIGURE 11-9. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (TEMPERATURE DEPENDENCE).

e. Angular Spectral Reflectance (Wavelength Dependence)

A total of 32 sets of experimental data were located for the wavelength dependence of the angular spectral reflectance of vitreous silica. One additional data set for synthetic quartz was located and included. The data are listed in Table 11-17 and shown in Figures 11-10 and 11-11. Specimen characterization and measurement information for the data are given in Table 11-16. Curves 20 and 21 are not shown on Figures 11-10 and 11-11, since the computer plotting routine cannot plot 33 curves.

The data above 1 μm are all for 293 K and is widely spaced. Lines connecting such widely spaced points (see Figure 11-11) do not imply a smooth curve connecting the points but are used for ease in visualizing the points belonging to the same curve.

Using the Fresnel equations, a set of provisional values was generated for angular spectral reflectance for unpolarized radiation (see Eqs. (2.4-1)-(2.4-5)). The values are for angles of incidence and reflection of 40°, for a temperature of 293 K, and hold within the wavelength range of 7.0-16.0 μm for an optically smooth specimen. The provisional values are listed in Table 11-15 and shown in Figure 11-10. An uncertainty within 30% is assigned.

TABLE 11-15. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ	λ	ρ
OPTICALLY SMOOTH $\theta = \theta' = 40°$ T = 293		OPTICALLY SMOOTH $\theta = \theta' = 40°$ T = 293 (CONT.)	
7.00	0.001	10.4	0.151
7.10	0.001	10.6	0.119
7.20	0.000	10.8	0.118
7.30	0.000	11.0	0.110
7.40	0.001	11.2	0.104
7.50	0.002	11.4	0.098
7.60	0.005	11.6	0.092
7.70	0.019	11.8	0.085
7.80	0.050	12.0	0.084
7.90	0.178	12.2	0.090
8.00	0.312	12.4	0.104
8.10	0.423	12.6	0.113
8.20	0.412	12.8	0.125
8.30	0.385	13.0	0.117
8.40	0.391	13.2	0.109
8.50	0.415	13.4	0.104
8.60	0.459	13.6	0.096
8.65	0.493	13.8	0.088
8.70	0.545	14.0	0.083
8.75	0.586	14.2	0.079
8.80	0.646	14.4	0.152
8.85	0.688	14.6	0.072
8.90	0.707	16.0	0.045
8.95	0.720		
9.00	0.670		
9.05	0.614		
9.10	0.466		
9.15	0.478		
9.20	0.473		
9.30	0.452		
9.35	0.416		
9.40	0.313		
9.50	0.344		
9.60	0.314		
9.70	0.286		
9.80	0.255		
9.90	0.233		
10.0	0.209		
10.2	0.172		

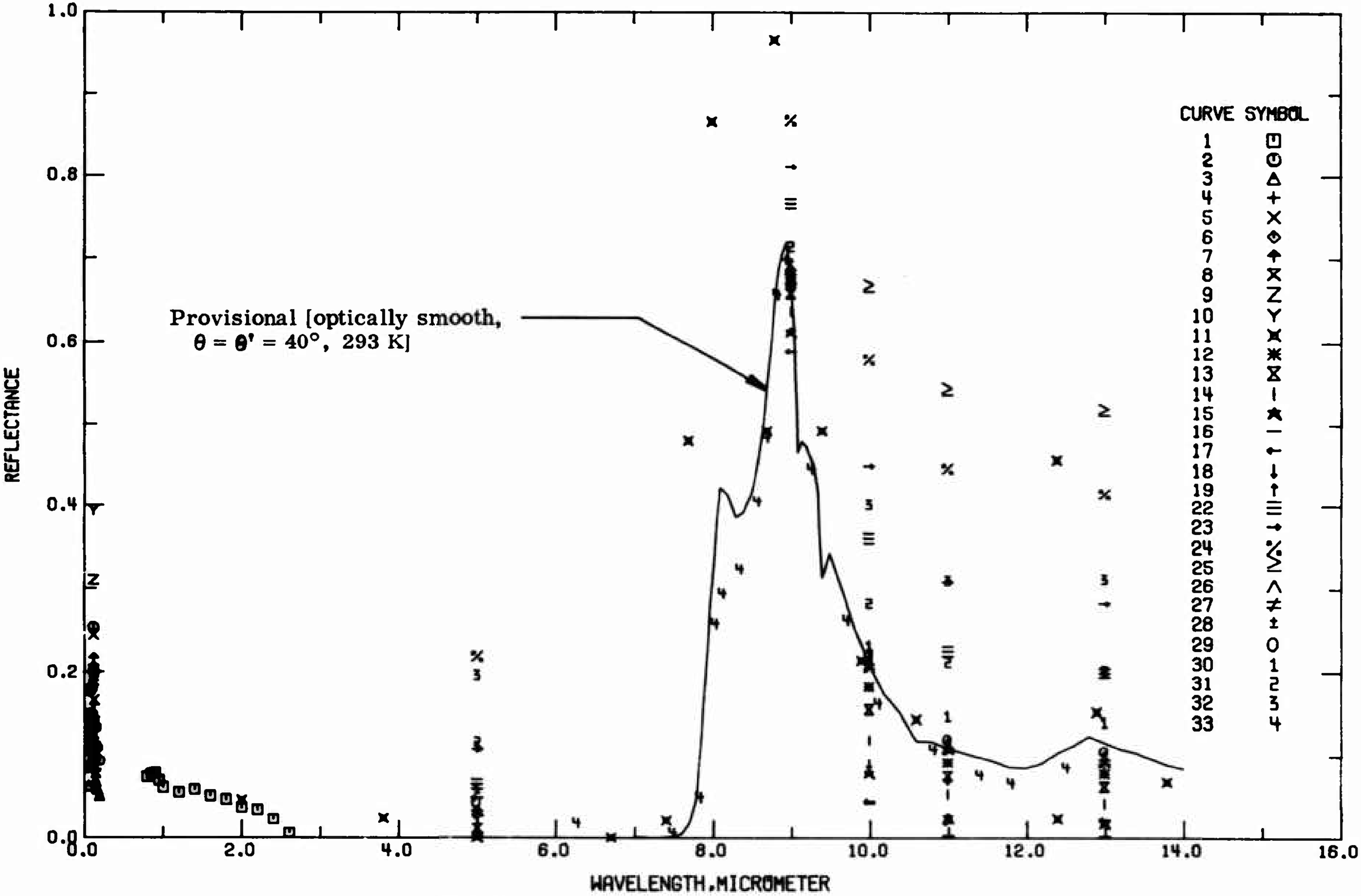


FIGURE 11-10. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

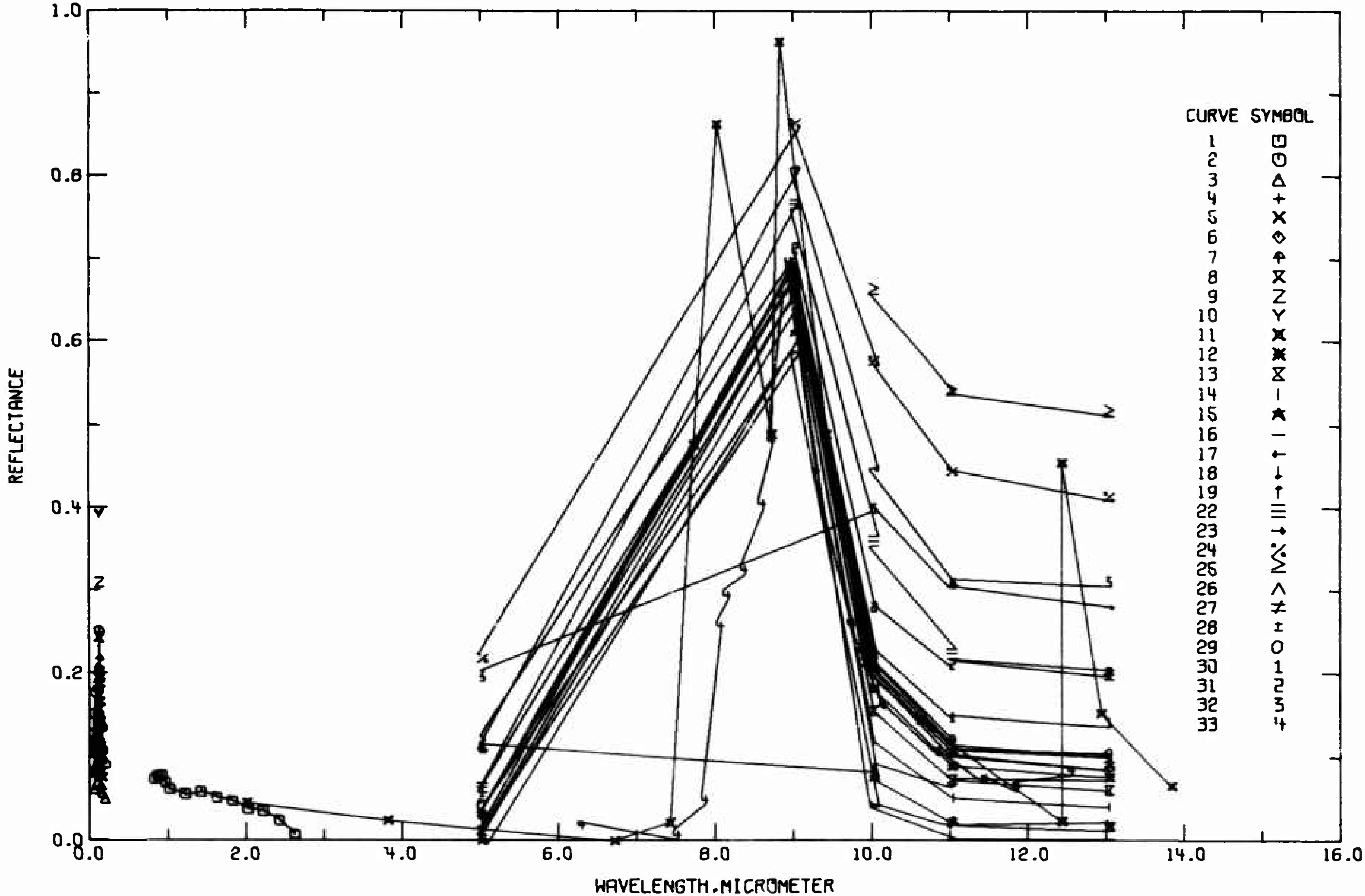


FIGURE 11-11. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

TABLE 11-16. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF SILICA (VITREOUS) (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, µm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T27141	Bogdan, L.	1964	0.80-2.6	293	Fused quartz	Disk specimen 0.375 in. in diameter and 0.0625 in. thick; clear fused quartz blank; aluminum mirror used as reference standard, reported measurements corrected; data from figure; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 45^\circ$, $\theta' = 45^\circ$.
2	T36689	Rabinovitch, K., Canfield, L.R., and Madden, R.P.	1965	0.056-0.19	293	Silica	Specimen 6 mm thick; measured in vacuum with the plane of incidence perpendicular to exit slit of the monochromator; measurement temperature not given explicitly, assumed to be 293 K; $\theta = 45^\circ$, $\theta' = 45^\circ$.
3	T36689	Rabinovitch, K., et al.	1965	0.058-0.19	293	Silica	The above specimen except measured with the plane of incidence parallel to exit slit of the monochromator.
4	T47322	Platzoder, K. and Steinmann, W.	1968	0.057-0.15	293	Fused quartz, type Suprasil	Specimens 1 mm thick; carefully cleaned and outgassed before measurement; samples supplied by Quarzschmelze Heraeus-Hanau; temperature specified as room temperature, 293 K assigned; $\theta = 20^\circ$.
5	T47322	Platzoder, K. and Steinmann, W.	1968	0.059-0.15	423	Fused quartz, type Suprasil	Similar to the above specimen except measured at 423 K.
6	T47322	Platzoder, K. and Steinmann, W.	1968	0.1216	293	Fused quartz, type Suprasil	Similar to the above specimen except temperature presumed to be room temperature, 293 K assigned; $\theta = 40^\circ$.
7	T47322	Platzoder, K. and Steinmann, W.	1968	0.1216	293	Fused quartz, type Suprasil	Similar to the above specimen; $\theta = 50^\circ$.
8	T47322	Platzoder, K. and Steinmann, W.	1968	0.1216	293	Fused quartz, type Suprasil	Similar to the above specimen; $\theta = 60^\circ$.
9	T47322	Platzoder, K. and Steinmann, W.	1968	0.1216	293	Fused quartz, type Suprasil	Similar to the above specimen; $\theta = 70^\circ$.
10	T47322	Platzoder, K. and Steinmann, W.	1968	0.1216	293	Fused quartz, type Suprasil	Similar to the above specimen; $\theta = 76^\circ$.
11	T30100	McCarthy, D.E.	1963	2.0-50	293	Quartz	Synthetic; specimen 10 mm thick; ground and polished to a flatness of seven fringes or better; reference standard was aluminum mirror; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; Beckman IR-5A used in 2-16 µm range and Beckman IR-7 with CsI interchange used in 12.5-50 µm range; $\theta = 30^\circ$, $\theta' = 30^\circ$.
12	T76947	General Dynamics Convair Aerospace Division	1974	9.0-22	293	Optosil 1, Convair Sample F	Specimen thickness 0.125 in.; polished disk; specimen provided by Aerospace Corp. who obtained it from Amersil, Inc., Hillside, New Jersey; measurements made using the General Dynamics Convair Aerospace ellipsoidal reflectometer and a Perkin Elmer Model 210 monochromator for dispersion and Advanced Ballistic Missile Defense Agency wire grid polarizers which were mounted as close as possible to the thermocouple detector; data gathered at atmospheric pressure; measurement temperature specified as room temperature, 293 K assigned; absolute reflectance determined directly; reflectance values reported are for component parallel to plane of incidence; five readings taken and average used in determining reflectance; data from figure; $\theta = 20^\circ$, $\theta' = 20^\circ$.
13	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 30^\circ$, $\theta' = 30^\circ$.

TABLE 11-16. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF SILICA (VITREOUS) (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
14	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 40°$, $\theta' = 40°$.
15	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 50°$, $\theta' = 50°$.
16	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 60°$, $\theta' = 60°$.
17	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 70°$, $\theta' = 70°$.
18	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 75°$, $\theta' = 75°$.
19	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen except reflectance measurements reported are for the component perpendicular to the plane of incidence; $\theta = 20°$, $\theta' = 20°$.
20	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 30°$, $\theta' = 30°$.
21	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 40°$, $\theta' = 40°$.
22	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 50°$, $\theta' = 50°$.
23	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 60°$, $\theta' = 60°$.
24	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 70°$, $\theta' = 70°$.
25	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 75°$, $\theta' = 75°$.
26	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen except reflectance values reported are for average of polarized components; $\theta = 20°$, $\theta' = 20°$.
27	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 30°$, $\theta' = 30°$.

TABLE 11-16. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF SILICA (VITREOUS) (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
28	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 40°$, $\theta' = 40°$.
29	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 50°$, $\theta' = 50°$.
30	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 60°$, $\theta' = 60°$.
31	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 70°$, $\theta' = 70°$.
32	T76947	General Dynamics Convair Aerospace Division	1974	5.0-22	293	Optosil 1, Convair Sample F	The above specimen; $\theta = 75°$, $\theta' = 75°$.
33	T40853	Perry, C.H. and Wrigley, J.D., Jr.	1967	7-32	293	Fused quartz	Two faces polished; smooth values from figure; measurement temperature specified as room temperature, 293 K assigned; $\theta = 15°$, $\theta' = 15°$.

TABLE 11-17. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 293.	
0.800	0.073
0.850	0.077
0.900	0.078
0.950	0.069
1.00	0.061
1.20	0.055
1.40	0.058
1.60	0.051
1.80	0.047
2.00	0.038
2.20	0.035
2.40	0.024
2.60	0.007
CURVE 2	
T = 298.	
0.0584	0.150
0.0736	0.176
0.1026	0.160
0.1216	0.252
0.1436	0.136
0.1606	0.110
0.1930	0.093
CURVE 3	
T = 298.	
0.0584	0.062
0.0736	0.091
0.1026	0.095
0.1216	0.149
0.1436	0.067
0.1606	0.058
0.1930	0.051
CURVE 4	
T = 293.	
0.0574	0.082
0.0633	0.100
0.0681	0.115
0.0702	0.119
0.0721	0.121
0.0748	0.119
0.0779	0.108
0.0813	0.104
0.0836	0.107
0.0871	0.126
0.0877	0.132
0.0894	0.134
0.0902	0.130
0.0932	0.116
0.0947	0.115
0.0978	0.119
0.1034	0.146
0.1046	0.150
0.1063	0.153
0.1075	0.151
0.1092	0.141
0.1104	0.132
0.1139	0.113
0.1150	0.111
0.1167	0.113
0.1201	0.201
0.1210	0.203
0.1221	0.200
0.1279	0.161
0.1316	0.135
0.1375	0.117
0.1407	0.108
0.1436	0.100
0.1465	0.093
0.1491	0.088
0.1216	0.202
CURVE 5	
T = 423.	
0.0586	0.081
0.0684	0.111
0.0747	0.114
0.0788	0.106
0.0838	0.106
0.0873	0.128
0.0908	0.129
0.0919	0.122
0.0956	0.116
0.0978	0.120
0.1026	0.134
0.1067	0.146
0.1080	0.142
0.1127	0.118
0.1169	0.116
0.1177	0.138
0.1195	0.194
0.1215	0.203
0.1243	0.188
0.1277	0.166
0.1307	0.142
0.1404	0.102
0.1491	0.084
0.1547	0.077
0.1216	0.202
CURVE 6	
T = 298.	
0.1216	0.207
CURVE 7	
T = 298.	
0.1216	0.217
CURVE 8	
T = 298.	
0.1216	0.244
CURVE 9	
T = 298.	
0.1216	0.310
CURVE 10	
T = 298.	
0.1216	0.393
CURVE 11	
T = 293.	
2.0	0.046
3.8	0.025
6.7	0.000
7.4	0.022
7.7	0.479
8.0	0.865
8.7	0.491
8.8	0.964
9.4	0.491
9.9	0.214
10.6	0.144
12.4	0.024
12.4	0.457
12.9	0.152
13.8	0.066
14.3	0.131
15.0	0.065
16.3	0.051
17.3	0.025
17.7	0.181
17.9	0.000
18.6	0.000
19.2	0.536
19.6	0.848
CURVE 11(CONT.)	
20.1	0.897
21.2	0.931
21.8	0.896
22.3	0.509
24.3	0.050
24.7	0.762
26.9	0.256
27.9	0.208
35.5	0.118
36.5	0.104
37.2	0.221
38.7	0.167
39.9	0.147
41.1	0.142
43.2	0.117
45.2	0.081
46.9	0.031
48.4	0.000
CURVE 12	
T = 293.	
9.0	0.670
10.0	0.182
11.0	0.091
13.0	0.077
16.0	0.040
22.0	0.372
CURVE 13	
T = 293.	
5.0	0.012
9.0	0.657
10.0	0.155
11.0	0.074
13.0	0.061
16.0	0.031
22.0	0.350
CURVE 14	
T = 293.	
5.0	0.007
9.0	0.637
10.0	0.120
11.0	0.052
13.0	0.041
16.0	0.018
22.0	0.314
CURVE 15	
T = 293.	
5.0	0.000
9.0	0.612
10.0	0.077
11.0	0.025
13.0	0.018
16.0	0.006
22.0	0.275
CURVE 16	
T = 293.	
5.0	0.006
9.0	0.588
10.0	0.042
11.0	0.003
13.0	0.002
16.0	0.003
22.0	0.236
CURVE 17	
T = 293.	
5.0	0.048
9.0	0.588
10.0	0.044
11.0	0.019
13.0	0.023
16.0	0.041

TABLE 11-17. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 17(CONT.)	
22.0	0.230
CURVE 18	
T = 293.	
5.0	0.111
10.0	0.089
11.0	0.070
13.0	0.079
16.0	0.108
22.0	0.267
CURVE 19	
T = 293.	
5.0	0.024
9.0	0.693
10.0	0.222
11.0	0.117
13.0	0.100
16.0	0.053
22.0	0.411
CURVE 20	
T = 293.	
5.0	0.029
9.0	0.710
10.0	0.251
11.0	0.138
13.0	0.119
16.0	0.064
22.0	0.436
CURVE 21	
T = 293.	
5.0	0.041
9.0	0.734
10.0	0.297
CURVE 21(CONT.)	
11.0	0.171
13.0	0.149
16.0	0.084
22.0	0.475
CURVE 22	
T = 293.	
5.0	0.064
9.0	0.766
10.0	0.361
11.0	0.225
13.0	0.199
16.0	0.122
22.0	0.528
CURVE 23	
T = 293.	
5.0	0.109
9.0	0.811
10.0	0.450
11.0	0.308
13.0	0.281
16.0	0.190
22.0	0.603
CURVE 24	
T = 293.	
5.0	0.219
9.0	0.867
10.0	0.578
11.0	0.447
13.0	0.415
16.0	0.315
22.0	0.708
CURVE 25	
T = 293.	
10.0	0.662
11.0	0.540
13.0	0.515
16.0	0.415
22.0	0.768
CURVE 26	
T = 293.	
5.0	0.033
9.0	0.674
10.0	0.206
11.0	0.109
13.0	0.091
16.0	0.051
22.0	0.409
CURVE 27	
T = 293.	
5.0	0.031
9.0	0.682
10.0	0.207
11.0	0.108
13.0	0.092
16.0	0.051
22.0	0.393
CURVE 28	
T = 293.	
5.0	0.034
9.0	0.685
10.0	0.212
11.0	0.113
13.0	0.099
16.0	0.055
22.0	0.399
CURVE 29	
T = 293.	
5.0	0.043
9.0	0.683
10.0	0.220
11.0	0.121
13.0	0.106
16.0	0.064
22.0	0.401
CURVE 30	
T = 293.	
5.0	0.059
9.0	0.688
10.0	0.232
11.0	0.148
13.0	0.141
16.0	0.086
22.0	0.409
CURVE 31	
T = 293.	
5.0	0.118
9.0	0.714
10.0	0.281
11.0	0.212
13.0	0.202
16.0	0.162
22.0	0.421
CURVE 32	
T = 293.	
5.0	0.196
10.0	0.401
11.0	0.310
13.0	0.312
16.0	0.264
22.0	0.558
CURVE 33	
T = 293.	
6.25	0.019
7.47	0.007
7.82	0.049
8.02	0.257
8.11	0.294
8.33	0.325
8.56	0.405
8.68	0.483
8.81	0.656
8.91	0.698
9.25	0.447
9.70	0.261
10.1	0.162
10.8	0.108
11.4	0.075
11.8	0.065
12.5	0.065
15.7	0.040
18.9	0.015
19.4	0.056
19.8	0.164
20.6	0.498
20.8	0.479
22.5	0.298
23.7	0.241
26.0	0.183
28.9	0.148
31.7	0.140

f. Normal Spectral Absorptance (Wavelength Dependence)

One set of experimental data was located for the wavelength dependence of the normal spectral absorptance of vitreous silica. In addition, two sets of experimental data for crystalline quartz was located. The data are listed in Table 11-20 and shown in Figures 11-12 and 11-13. Specimen characterization and measurement information for the data are given in Table 11-19.

The data of Bogdan [T27141] (curve 3) is for a temperature of 293 K and covers a wavelength range of 0.8 to 2.60 μm. That data was calculated from reflectance and transmittance data.

Calculations were carried out to determine the wavelength dependence of the normal spectral absorptance for radiation that is polarized perpendicular to the plane of incidence (curves 4-6), the absorptance that is parallel to the plane of incidence (curves 7-9), and the absorptance for unpolarized radiation (curves 10-12). The calculations used the Fresnel equations, Eqs. (2.4-1)-(2.4-5), together with Eq. (2.4-8). For a discussion of the index of refraction and absorption index data that were used in the calculations, see the section on the wavelength dependence of the normal spectral emittance.

Provisional values for the wavelength dependence of the normal spectral absorptance were generated. The values are listed in Table 11-18 and shown in Figure 11-12. The values here were equated to the provisional values for the wavelength dependence of the normal spectral emittance. Below 7 μm the provisional values apply to a 0.50 in. thick specimen of Corning 7940 vitreous silica at 293 K and Kirchhoff's law was used to equate the normal spectral absorptance to the normal spectral emittance. Above 7 μm the provisional values are the calculated values using the Fresnel equations for unpolarized radiation, Eqs. (2.4-1)-(2.4-5) and (2.4-8). The calculated values hold for an optically smooth specimen at 293 K that is opaque and the angle of incidence is 0°. An uncertainty of 30% is assigned. For more details see the section on the wavelength dependence of the normal spectral emittance for vitreous silica. The value of the normal spectral absorptance at 10.6 μm and 293 K is 0.89.

TABLE 11-13. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF SILICA (VITREOUS) (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α)

CORNING 7940, 1.27CM THICK, T = 293

λ	α
2.14	0.025
2.32	0.042
2.42	0.062
2.50	0.083
2.52	0.131
2.52	0.252
2.50	0.408
2.51	0.439
2.54	0.473
2.58	0.563
2.58	0.643
2.58	0.682
2.58	0.762
2.63	0.914
2.62	0.957
2.68	0.970
2.76	0.957
2.81	0.883
2.81	0.687
2.85	0.623
2.95	0.524
3.00	0.453
3.03	0.395
3.03	0.313
3.09	0.299
3.22	0.302
3.39	0.315
3.50	0.332
3.57	0.410
3.61	0.471
3.67	0.547
3.74	0.642
3.80	0.699
3.88	0.803
3.95	0.890
4.00	0.907
4.15	0.927
4.21	0.952
4.37	0.965

CORNING 7940, 1.27CM THICK, T = 293 (CONT.)

λ	α
4.49	0.970
4.55	0.970
4.66	0.974
4.81	0.973
4.99	0.973
5.00	0.974
5.27	0.979
5.56	0.986
5.77	0.986
5.88	0.986
6.00	0.986
6.18	0.989
6.40	0.993
6.62	0.994
6.78	0.993
6.90	0.993

OPTICALLY SMOOTH, T = 293

λ	α
7.00	0.999
7.10	1.000
7.20	1.000
7.30	1.000
7.40	1.000
7.50	0.999
7.60	0.997
7.70	0.990
7.80	0.980
7.90	0.949
8.00	0.865
8.10	0.732
8.20	0.686
8.30	0.694
8.40	0.664
8.50	0.632
8.60	0.578
8.65	0.539
8.70	0.479
8.75	0.433
8.80	0.368
8.85	0.321
8.90	0.298
8.95	0.281
9.00	0.330
9.05	0.382
9.10	0.535
9.15	0.470
9.20	0.526
9.30	0.547
9.35	0.584
9.40	0.689
9.50	0.657
9.60	0.687
9.70	0.716
9.80	0.748
9.90	0.771
10.0	0.795
10.2	0.834

OPTICALLY SMOOTH, T = 293 (CONT.)

λ	α
10.4	0.855
10.6	0.887
10.8	0.889
11.0	0.897
11.2	0.902
11.4	0.909
11.6	0.915
11.8	0.923
12.0	0.923
12.2	0.917
12.4	0.903
12.6	0.894
12.8	0.881
13.0	0.890
13.2	0.898
13.4	0.903
13.6	0.911
13.8	0.919
14.0	0.923
14.2	0.928
14.4	0.857
14.6	0.935
16.0	0.960

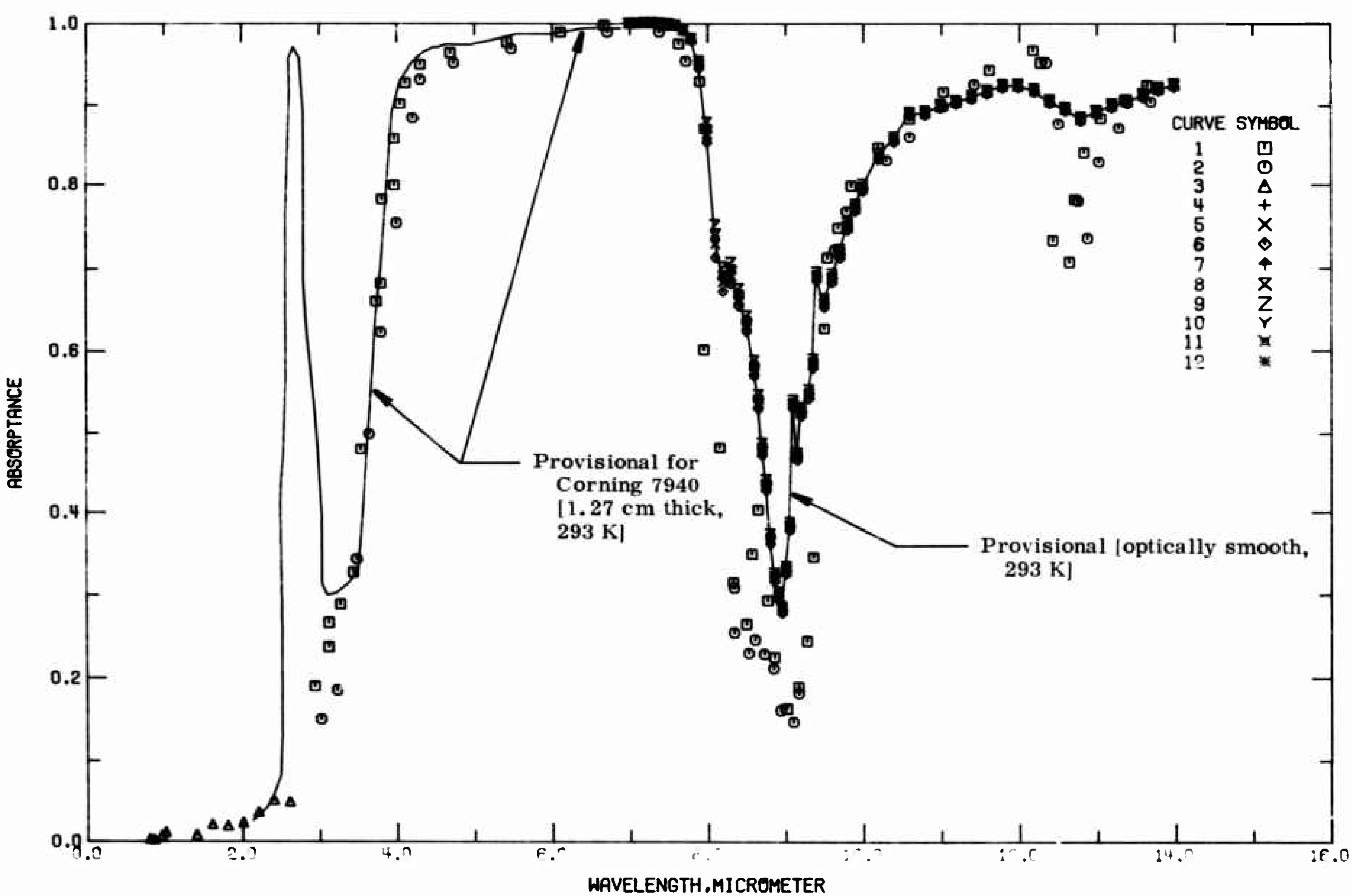


FIGURE 11-12. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

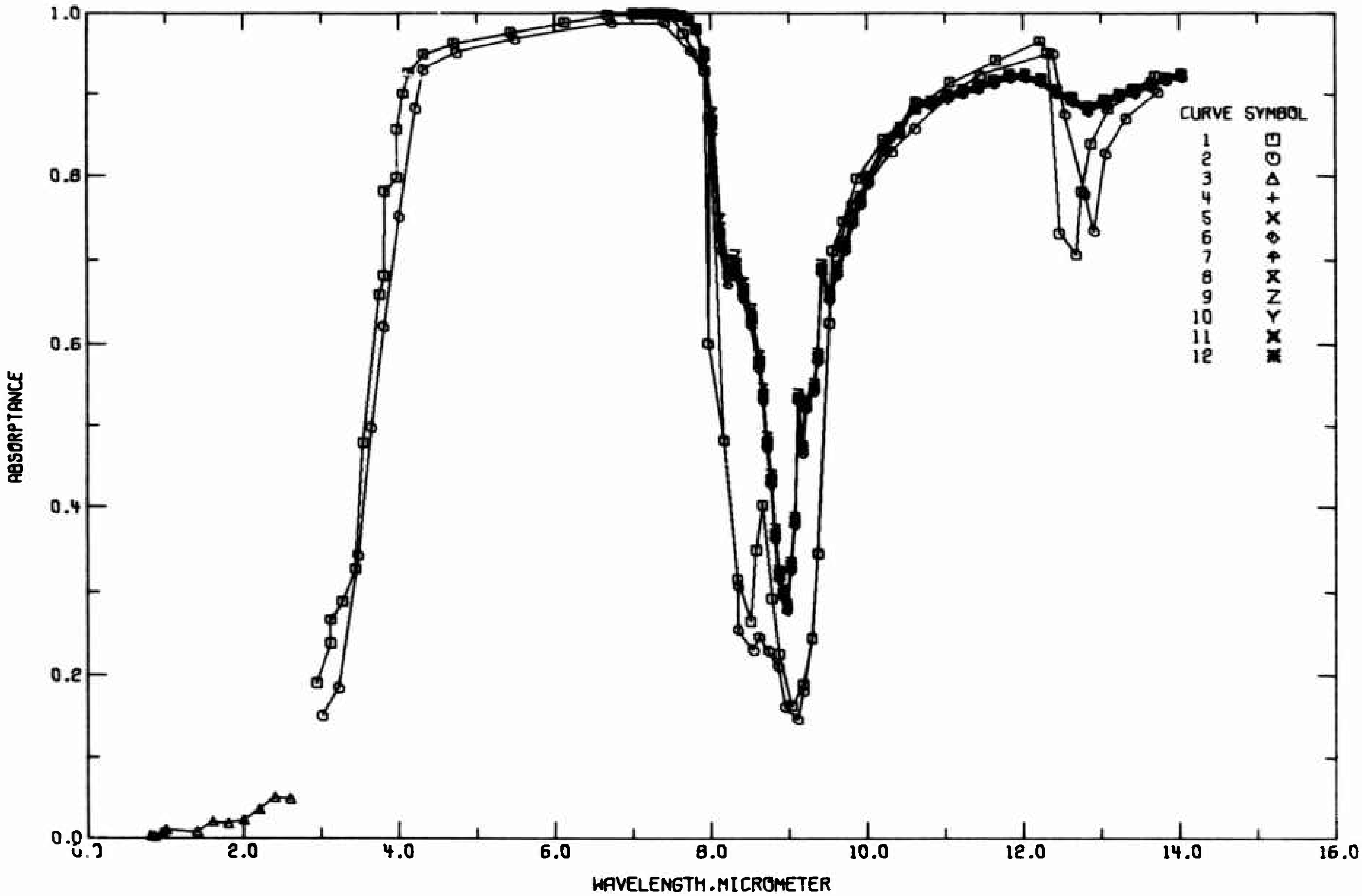


FIGURE 11-13. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

TABLE 11-19. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF SILICA(VITREOUS) (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T45698	Stierwalt, D.L., Bernstein, J.B., and Kirk, D.D.	1963	2.9-24	373	Crystalline Quartz	Measurement for ordinary ray; a Beckman IR-3 spectrophotometer, modified, used for measurement; this instrument evacuable and its temperature controlled by a water bath system; smooth values from figure; emittance measured, absorptance determined by applying Kirchoff's Law, θ=0°.
2	T45698	Stierwalt, D.L., et al.	1963	3.0-23	373	Crystalline Quartz	Similar to the above specimen except measurement made for extraordinary ray.
3	T27141	Bogdan, L.	1964	0.80-2.60	293	Fused Quartz	Disk specimen 0.375 in. in diameter and 0.0625 in. thick; clear fused quartz blank; data from figure; temperature not given explicitly, assumed to be 293 K; author calculates absorptance (θ) from $1.0-\rho(45°, 45°) - \tau(0°, 0°)$, angle θ presumed to be 0°.
4	A00012		1975	7.0-16	293		Calculations for fused silica performed for a homogeneous; smooth surface and for perpendicular component of radiation, equations (2.4-6), (2.4-1), (2.4-3), and (2.4-4); data for index of refraction, n, and absorption index, k, from [A00012]; θ=0°.
5	A00012		1975	7.0-16	293		Similar to the above specimen except θ=5°.
6	A00012		1975	7.0-16	293		Similar to the above specimen except θ=10°.
7	A00012		1975	7.0-16	293		Similar to the above specimen except for parallel component of radiation; equation (2.4-7) and θ=0°.
8	A00012		1975	7.0-16	293		Similar to the above specimen except θ=5°.
9	A00012		1975	7.0-16	293		Similar to the above specimen except θ=10°.
10	A00012		1975	7.0-16	293		Similar to the above specimen except for unpolarized radiation, equation (2.4-8) and θ=0°.
11	A00012		1975	7.0-16	293		Similar to the above specimen except θ=5°.
12	A00012		1975	7.0-16	293		Similar to the above specimen except θ=10°.

TABLE 11-20. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α	λ	α	λ	α	λ	α
CURVE 1		CURVE	1(CONT.)	CURVE 2		CURVE	2(CONT.)	CURVE	3(CONT.)	CURVE	4(CONT.)
T = 373.				T = 373.							
		10.60	0.881			12.88	0.734	1.40	0.008	9.30	0.5473
2.93	0.190	11.04	0.915	3.01	0.151	13.03	0.827	1.60	0.021	9.35	0.5836
3.11	0.238	11.63	0.942	3.22	0.185	13.29	0.870	1.80	0.019	9.40	0.6894
3.11	0.266	12.19	0.966	3.47	0.343	13.70	0.903	2.00	0.023	9.50	0.6567
3.26	0.288	12.29	0.951	3.64	0.499	14.13	0.923	2.20	0.036	9.60	0.6871
3.43	0.327	12.44	0.731	3.80	0.621	14.89	0.938	2.40	0.051	9.70	0.7159
3.53	0.479	12.65	0.706	4.00	0.752	15.73	0.959	2.60	0.049	9.80	0.7479
3.74	0.659	12.72	0.781	4.21	0.882	16.59	0.976			9.90	0.7705
3.80	0.681	12.84	0.839	4.31	0.930	16.96	0.987	CURVE 4		10.0	0.7950
3.81	0.781	13.06	0.882	4.74	0.951	17.43	0.989	T = 293.		10.2	0.8335
3.97	0.798	13.37	0.906	5.48	0.968	17.71	0.965			10.4	0.8548
3.97	0.856	13.66	0.923	6.72	0.988	17.97	0.896	7.00	0.99940	10.6	0.8874
4.05	0.900	14.16	0.934	7.39	0.988	18.22	0.668	7.10	0.99960	10.8	0.8886
4.12	0.926	14.39	0.893	7.73	0.953	18.35	0.558	7.20	0.9999	11.0	0.8971
4.31	0.949	14.60	0.916	7.91	0.928	18.43	0.524	7.30	0.9999	11.2	0.9023
4.70	0.963	14.99	0.924	7.95	0.600	18.75	0.478	7.40	0.9995	11.4	0.9085
5.43	0.976	16.28	0.958	7.97	0.869	19.12	0.472	7.50	0.9985	11.6	0.9152
6.12	0.988	17.72	0.986	8.15	0.481	19.41	0.502	7.60	0.9969	11.8	0.9225
6.68	0.997	18.39	0.996	8.33	0.307	19.59	0.586	7.70	0.9904	12.0	0.9229
7.46	0.997	18.87	0.996	8.33	0.254	19.89	0.383	7.80	0.9796	12.2	0.9172
7.64	0.974	19.16	0.983	8.52	0.230	19.98	0.322	7.90	0.9489	12.4	0.9034
7.91	0.928	19.36	0.947	8.60	0.246	20.13	0.302	8.00	0.8649	12.6	0.8937
7.97	0.869	19.48	0.861	8.72	0.229	20.36	0.355	8.10	0.7319	12.8	0.8814
7.95	0.600	19.52	0.651	8.84	0.211	20.50	0.448	8.20	0.6863	13.0	0.8899
8.15	0.481	19.87	0.395	8.93	0.161	20.65	0.518	8.30	0.6936	13.2	0.8982
8.32	0.314	20.06	0.249	9.09	0.147	21.08	0.554	8.40	0.6640	13.4	0.9030
8.49	0.264	20.37	0.196	9.16	0.181	21.64	0.590	8.50	0.6318	13.6	0.9113
8.56	0.349	20.71	0.165	9.27	0.244	21.95	0.618	8.60	0.5784	13.8	0.9190
8.64	0.402	21.06	0.155	9.35	0.345	22.24	0.659	8.65	0.5387	14.0	0.9234
8.76	0.292	21.55	0.173	9.50	0.625	22.53	0.699	8.70	0.4793	14.2	0.9277
8.85	0.225	21.84	0.202	9.54	0.711	22.76	0.725	8.75	0.4334	14.4	0.8567
9.01	0.163	22.15	0.294	9.63	0.719	23.45	0.779	8.80	0.3675	14.6	0.9348
9.16	0.189	22.38	0.448	9.79	0.766			8.85	0.3206	16.0	0.9602
9.27	0.244	22.51	0.577	10.30	0.829	CURVE 3		8.90	0.2982		
9.35	0.345	22.80	0.619	10.60	0.858	T = 293.		8.95	0.2813	CURVE 5	
9.50	0.625	23.07	0.672	11.03	0.897			9.00	0.3296	T = 293.	
9.54	0.711	23.24	0.719	11.43	0.924	0.800	0.003	9.05	0.3824		
9.68	0.746	23.41	0.774	12.36	0.951	0.850	0.002	9.10	0.5351	7.00	0.9994
9.85	0.797	23.88	0.840	12.51	0.875	0.950	0.007	9.15	0.4699	7.10	0.9996
10.20	0.845			12.76	0.779	1.00	0.011	9.20	0.5256	7.20	0.9998

TABLE 11-26. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α	λ	α	λ	α	λ	α
CURVE	5(CONT.)	CURVE	5(CONT.)	CURVE	6(CONT.)	CURVE	6(CONT.)	CURVE	7(CONT.)	CURVE	8(CONT.)
7.30	0.9999	11.2	0.9015	8.65	0.5295	14.0	0.9207	9.40	0.6894	7.50	0.9985
7.40	0.9995	11.4	0.9077	8.70	0.4719	14.2	0.9231	9.50	0.6567	7.60	0.9969
7.50	0.9985	11.6	0.9145	8.75	0.4259	14.4	0.9525	9.60	0.6871	7.70	0.9906
7.60	0.9968	11.8	0.9218	8.80	0.3610	14.6	0.9324	9.70	0.7159	7.80	0.9800
7.70	0.9903	12.0	0.9222	8.85	0.3150	15.0	0.9556	9.80	0.7479	7.90	0.9500
7.80	0.9792	12.2	0.9165	8.90	0.2931			9.90	0.7705	8.00	0.8681
7.90	0.9477	12.4	0.9026	8.95	0.2769	CURVE 7		10.0	0.7950	8.10	0.7370
8.00	0.8615	12.6	0.8923	9.00	0.3249	T = 293.		10.2	0.8335	8.20	0.6902
8.10	0.7268	12.8	0.8835	9.05	0.3775			10.4	0.8548	8.30	0.6970
8.20	0.6824	13.0	0.8891	9.10	0.5293	7.00	0.9994	10.6	0.8874	8.40	0.6668
8.30	0.6902	13.2	0.8974	9.15	0.4645	7.10	0.9996	10.8	0.8886	8.50	0.6344
8.40	0.6611	13.4	0.9023	9.20	0.5260	7.20	0.9999	11.0	0.8971	8.60	0.5809
8.50	0.6291	13.6	0.9105	9.30	0.5416	7.30	0.9999	11.2	0.9023	8.65	0.5409
8.60	0.5750	13.8	0.9183	9.35	0.5779	7.40	0.9995	11.4	0.9085	8.70	0.4814
8.65	0.5363	14.0	0.9227	9.40	0.6838	7.50	0.9985	11.5	0.9152	8.75	0.4353
8.70	0.4772	14.2	0.9271	9.50	0.6511	7.60	0.9969	11.8	0.9225	8.80	0.3692
8.75	0.4315	14.4	0.8557	9.60	0.6816	7.70	0.9904	12.0	0.9229	8.85	0.3220
8.80	0.3659	14.6	0.9342	9.70	0.7105	7.80	0.9796	12.2	0.9172	8.90	0.2994
8.85	0.3192	16.0	0.9598	9.80	0.7428	7.90	0.9459	12.4	0.9034	8.95	0.2824
8.90	0.2969			9.90	0.7655	8.00	0.8649	12.6	0.8937	9.00	0.3307
8.95	0.2802	CURVE 6		10.0	0.7902	8.10	0.7319	12.8	0.8814	9.05	0.3837
9.00	0.3284	T = 293.		10.2	0.8292	8.20	0.6863	13.0	0.8899	9.10	0.5365
9.05	0.3812			10.4	0.8508	8.30	0.6936	13.2	0.8982	9.15	0.4713
9.10	0.5336	7.00	0.9993	10.6	0.8840	8.40	0.6640	13.4	0.9030	9.20	0.5270
9.15	0.4686	7.10	0.9995	10.8	0.8852	8.50	0.6318	13.5	0.9113	9.30	0.5487
9.20	0.5242	7.20	0.9998	11.0	0.8938	8.60	0.5784	13.8	0.9190	9.35	0.5851
9.30	0.5459	7.30	0.9999	11.2	0.8992	8.65	0.5387	14.0	0.9234	9.40	0.6908
9.35	0.5822	7.40	0.9995	11.4	0.9054	8.70	0.4793	14.2	0.9277	9.50	0.6581
9.40	0.6880	7.50	0.9984	11.6	0.9123	8.75	0.4334	14.4	0.8567	9.60	0.6885
9.50	0.6553	7.60	0.9966	11.8	0.9197	8.80	0.3675	14.6	0.9348	9.70	0.7172
9.60	0.6858	7.70	0.9897	12.0	0.9231	8.85	0.3206	16.0	0.9602	9.80	0.7492
9.70	0.7146	7.80	0.9779	12.2	0.9144	8.90	0.2982			9.90	0.7717
9.80	0.7466	7.90	0.9439	12.4	0.9002	8.95	0.2813	CURVE 8		10.0	0.7961
9.90	0.7692	8.00	0.8510	12.6	0.8903	9.00	0.3296	T = 293.		10.2	0.8346
10.0	0.7938	8.10	0.7112	12.8	0.8779	9.05	0.3824			10.4	0.8558
10.2	0.8324	8.20	0.6705	13.0	0.8865	9.10	0.5351	7.00	0.9994	10.6	0.8883
10.4	0.8538	8.30	0.6800	13.2	0.8950	9.15	0.4699	7.10	0.9996	10.8	0.8895
10.6	0.8866	8.40	0.6527	13.4	0.8999	9.20	0.5256	7.20	0.9999	11.0	0.8979
10.8	0.8878	8.50	0.6212	13.6	0.9083	9.30	0.5473	7.30	0.9999	11.2	0.9031
11.0	0.8963	8.60	0.5686	13.8	0.9162	9.35	0.5836	7.40	0.9995	11.4	0.9092

TABLE 11-20. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α
CURVE 8 (CONT.)	
11.6	0.9159
11.8	0.9231
12.0	0.9235
12.2	0.9179
12.4	0.9042
12.6	0.8945
12.8	0.8823
13.0	0.8907
13.2	0.8990
13.4	0.9038
13.6	0.9120
13.8	0.9197
14.0	0.9241
14.2	0.9283
14.4	0.8577
14.6	0.9354
16.0	0.9606
CURVE 9	
T = 293.	
7.00	0.9994
7.10	0.9996
7.20	0.9999
7.30	0.9999
7.40	0.9995
7.50	0.9986
7.60	0.9971
7.70	0.9911
7.80	0.9813
7.90	0.9536
8.00	0.8777
8.10	0.7503
8.20	0.7008
8.30	0.7062
8.40	0.6747
8.50	0.6419
8.60	0.5878
8.65	0.5475
8.70	0.4874

λ	α
CURVE 9 (CONT.)	
8.75	0.4408
8.80	0.3740
8.85	0.3261
8.90	0.3032
8.95	0.2856
9.00	0.3342
9.05	0.3874
9.10	0.5409
9.15	0.4753
9.20	0.5312
9.30	0.5529
9.35	0.5894
9.40	0.6949
9.50	0.6623
9.60	0.6926
9.70	0.7212
9.80	0.7531
9.90	0.7754
10.0	0.7997
10.2	0.8378
10.4	0.8588
10.6	0.8909
10.8	0.8920
11.0	0.9004
11.2	0.9055
11.4	0.9115
11.6	0.9181
11.8	0.9251
12.0	0.9256
12.2	0.9201
12.4	0.9066
12.6	0.8970
12.8	0.8849
13.0	0.8933
13.2	0.9014
13.4	0.9062
13.6	0.9142
13.8	0.9218
14.0	0.9261
14.2	0.9302

λ	α
CURVE 9 (CONT.)	
14.4	0.8609
14.6	0.9372
16.0	0.9613
CURVE 10	
T = 293.	
7.00	0.9994
7.10	0.9996
7.20	0.9999
7.30	0.9999
7.40	0.9995
7.50	0.9985
7.60	0.9969
7.70	0.9904
7.80	0.9796
7.90	0.9489
8.00	0.8649
8.10	0.7319
8.20	0.6863
8.30	0.6936
8.40	0.6640
8.50	0.6318
8.60	0.5784
8.65	0.5387
8.70	0.4793
8.75	0.4334
8.80	0.3675
8.85	0.3206
8.90	0.2982
8.95	0.2813
9.00	0.3296
9.05	0.3824
9.10	0.5351
9.15	0.4699
9.20	0.5256
9.30	0.5473
9.35	0.5836
9.40	0.6894
9.50	0.6567

λ	α
CURVE 10 (CONT.)	
9.60	0.6871
9.70	0.7159
9.80	0.7479
9.90	0.7765
10.0	0.7950
10.2	0.8335
10.4	0.8548
10.6	0.8874
10.8	0.8886
11.0	0.8971
11.2	0.9023
11.4	0.9085
11.6	0.9152
11.8	0.9225
12.0	0.9229
12.2	0.9172
12.4	0.9034
12.6	0.8937
12.8	0.8814
13.0	0.8899
13.2	0.8982
13.4	0.9030
13.6	0.9113
13.8	0.9190
14.0	0.9234
14.2	0.9277
14.4	0.8567
14.6	0.9348
16.0	0.9602
CURVE 11	
T = 293.	
7.00	0.9994
7.10	0.9996
7.20	0.9999
7.30	0.9999
7.40	0.9995
7.50	0.9985
7.60	0.9969

λ	α
CURVE 11 (CONT.)	
7.70	0.9904
7.80	0.9796
7.90	0.9489
8.00	0.8648
8.10	0.7319
8.20	0.6863
8.30	0.6936
8.40	0.6640
8.50	0.6318
8.60	0.5784
8.65	0.5386
8.70	0.4793
8.75	0.4334
8.80	0.3675
8.85	0.3206
8.90	0.2982
8.95	0.2813
9.00	0.3296
9.05	0.3824
9.10	0.5351
9.15	0.4699
9.20	0.5256
9.30	0.5473
9.35	0.5836
9.40	0.6894
9.50	0.6567
9.60	0.6871
9.70	0.7159
9.80	0.7479
9.90	0.7765
10.0	0.7950
10.2	0.8335
10.4	0.8548
10.6	0.8874
10.8	0.8886
11.0	0.8971
11.2	0.9023
11.4	0.9085
11.6	0.9152
11.8	0.9225

λ	α
CURVE 11 (CONT.)	
12.0	0.9229
12.2	0.9172
12.4	0.9034
12.6	0.8937
12.8	0.8814
13.0	0.8899
13.2	0.8982
13.4	0.9030
13.6	0.9113
13.8	0.9190
14.0	0.9234
14.2	0.9277
14.4	0.8567
14.6	0.9348
16.0	0.9602
CURVE 12	
T = 293.	
7.00	0.9994
7.10	0.9996
7.20	0.9999
7.30	0.9999
7.40	0.9995
7.50	0.9985
7.60	0.9969
7.70	0.9904
7.80	0.9796
7.90	0.9488
8.00	0.8643
8.10	0.7307
8.20	0.6856
8.30	0.6931
8.40	0.6637
8.50	0.6316
8.60	0.5782
8.65	0.5385
8.70	0.4792
8.75	0.4334
8.80	0.3675

TABLE 11-20. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α
CURVE 12(CONT.)		CURVE 12(CONT.)	
8.85	0.3206	16.0	0.9602
8.90	0.2982		
8.95	0.2813		
9.00	0.3236		
9.05	0.3824		
9.10	0.5351		
9.15	0.4639		
9.20	0.5256		
9.30	0.5473		
9.35	0.5836		
9.40	0.6894		
9.50	0.6567		
9.60	0.6871		
9.70	0.7159		
9.80	0.7479		
9.90	0.7704		
10.0	0.7949		
10.2	0.8335		
10.4	0.8548		
10.6	0.8874		
10.8	0.8886		
11.0	0.8971		
11.2	0.9023		
11.4	0.9084		
11.6	0.9152		
11.8	0.9224		
12.0	0.9228		
12.2	0.9172		
12.4	0.9034		
12.6	0.8936		
12.8	0.8813		
13.0	0.8899		
13.2	0.8982		
13.4	0.9030		
13.6	0.9113		
13.8	0.9190		
14.0	0.9234		
14.2	0.9277		
14.4	0.8567		
14.6	0.9348		

g. Angular Spectral Absorptance (Wavelength Dependence)

No experimental data sets were found for the wavelength dependence of the angular spectral absorptance of vitreous silica. However, a set of provisional values is listed in Table 11-21 and shown in Figure 11-14. The values were calculated using the Fresnel equations for specular reflection for unpolarized radiation (see Eqs. (2.4-1)-(2.4-5) and (2.4-8)). The context within which the provisional values are valid is a temperature of 293 K, a wavelength range of 7.0 to 16.0 μm, an angle of incidence, θ, of 40°, and an optically smooth specimen. An uncertainty of within 30% is assigned. See the section on the wavelength dependence of the angular spectral emittance for more discussion of the reasoning for the assignment of this uncertainty.

TABLE 11-21. PROVISIONAL ANGULAR SPECTRAL ABSORPTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α
OPTICALLY SMOOTH θ = 40° T = 293		OPTICALLY SMOOTH θ = 40° T = 293 (CONT.)	
7.00	0.993	10.4	0.849
7.10	0.999	10.6	0.881
7.20	1.000	10.8	0.882
7.30	1.000	11.0	0.890
7.40	0.999	11.2	0.896
7.50	0.998	11.4	0.902
7.60	0.995	11.6	0.908
7.70	0.981	11.8	0.915
7.80	0.950	12.0	0.916
7.90	0.822	12.2	0.910
8.00	0.688	12.4	0.896
8.10	0.577	12.6	0.887
8.20	0.588	12.8	0.875
8.30	0.615	13.0	0.883
8.40	0.609	13.2	0.891
8.50	0.585	13.4	0.896
8.60	0.541	13.6	0.904
8.65	0.507	13.8	0.912
8.70	0.455	14.0	0.917
8.75	0.414	14.2	0.921
8.80	0.354	14.4	0.848
8.85	0.312	14.6	0.928
8.90	0.293	16.0	0.954
8.95	0.280		
9.00	0.330		
9.05	0.384		
9.10	0.534		
9.15	0.472		
9.20	0.527		
9.30	0.548		
9.35	0.564		
9.40	0.687		
9.50	0.656		
9.60	0.686		
9.70	0.714		
9.80	0.745		
9.90	0.767		
10.0	0.791		
10.2	0.828		

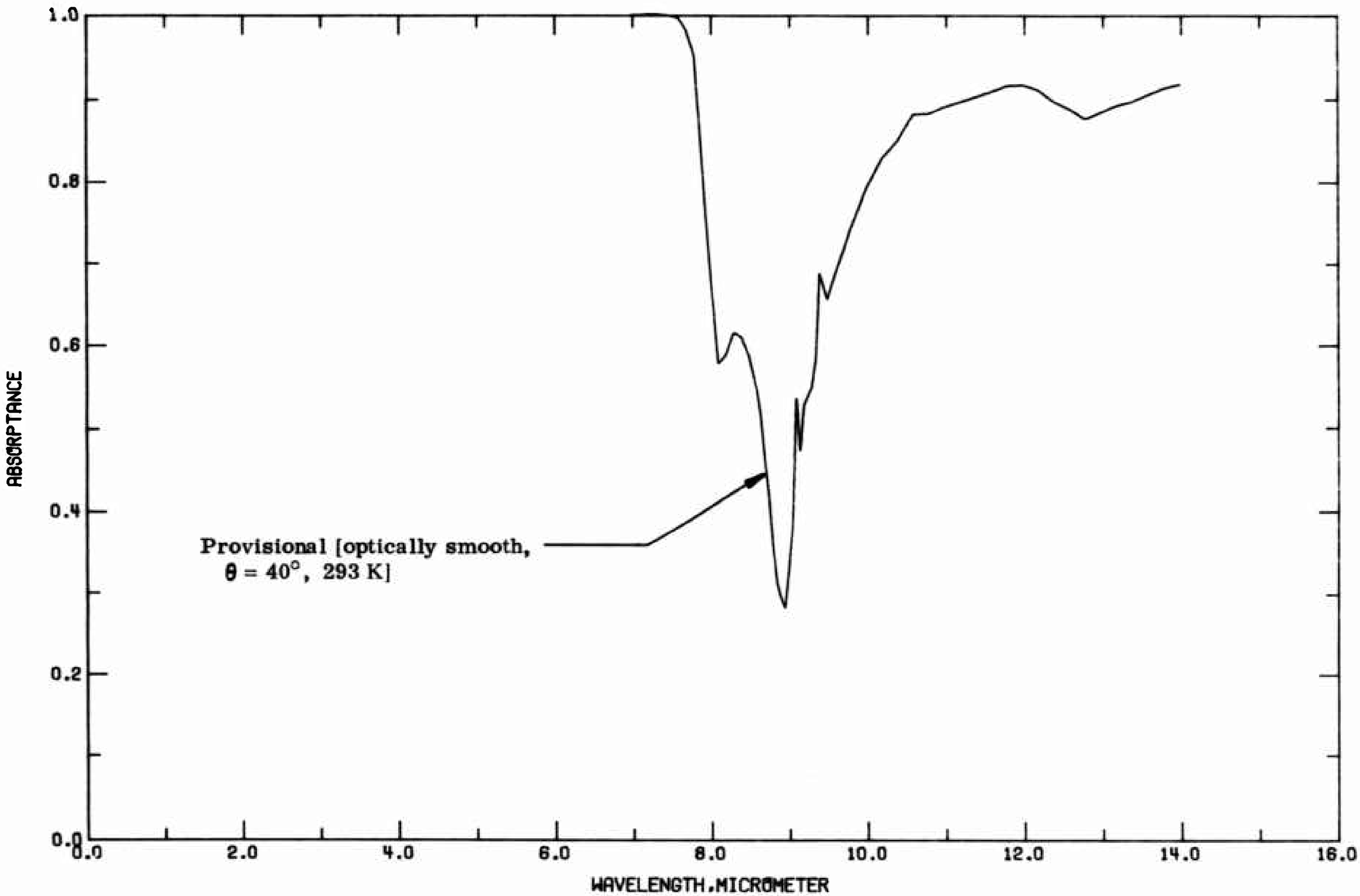


FIGURE 11-14. PROVISIONAL ANGULAR SPECTRAL ABSORPTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

h. Normal Spectral Transmittance (Wavelength Dependence)

A total of 38 sets of experimental data were located and processed for the category of the wavelength dependence of the normal spectral transmittance of vitreous silica. The data are listed in Table 11-24 and shown in Figures 11-15 to 11-18. Specimen characterization and measurement information for the data are given in Table 11-23. The plots of the raw data connected by lines is broken up into two figures, Figure 11-17 and 11-18. The reason for this is that the plotting routine can only plot 32 curves without repeating a symbol used to plot a curve. Therefore, it was decided to plot curves 1 through 30 on Figure 11-17 and curves 31 through 38 on Figure 11-18. The same idea was used in showing the provisional values against the background of data points in Figures 11-15 and 11-16.

With the exception of the work of Gillespie, Olsen, and Nichols [T38674] (curves 2-5) and Kroeckel [T31344] (curves 34-36), all the reported data are for room temperature. Most of the room temperature data show the usual behavior - a transmittance over 80% between 1 and 2 μm and a cut off between 4 and 5 μm. The data not showing this behavior are for a specimen 0.022 mm thick (curves 15 and 16), a specimen 6500 Å thick (curve 17), opal (curve 18), silica gel (curve 20), and fused quartz in 2 gm polyethylene binder (curve 21).

A strong word of caution needs to be expressed concerning the absorption band that can exist in the area of 2.8 to 2.9 μm. The decrease in transmittance due to this absorption band can be very large (see curves 22, 24, and 26) or barely exist (see curve 25). This decrease depends on the type of vitreous silica.

Provisional values, for various situations, are listed in Table 11-22 and shown in Figures 11-15 and 11-16. One set of values is for Dynasil 1000 and holds for a 10 mm thick specimen at 293 K with a coverage of wavelength from 0.157 to 4.39 μm. Another is applicable to a 1 mm thick specimen of Optosil 1 at 293 K. The transmittance is less than 0.005 from 5 to 16 μm. The only high temperature data that includes 3.8 μm is the data of Gillespie [T38674] (curves 2-5) for the G.E. type 106 fused quartz kind of vitreous silica. To cover the effect of temperature, two provisional curves for G.E. type 106 fused quartz are given. Both are for a 2.8 mm thick specimen and polished. One curve is for a temperature of 373 K and the other is for 673 K. An uncertainty of within 30% is assigned to all these curves because the transmittance values are low in some places with a consequently high percentage and because there is not confirmatory data for individual data sets.

TABLE 11-22. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
DYNASIL 1000 10MM THICK T = 293		DYNASIL 1000 10MM THICK T = 293 (CONT.)		DYNASIL 1000 10MM THICK T = 293 (CONT.)		GE TYPE 106 2.8MM THICK T = 373		GE TYPE 106 2.8MM THICK T = 673		OPTOSIL 1 1MM THICK T = 293	
0.157	0.017	1.48	0.928	3.93	0.118	2.00	0.933	2.00	0.933	5.0	0.005
0.160	0.243	1.55	0.930	4.00	0.098	2.30	0.929	2.30	0.928	5.5	0.005
0.166	0.500	1.64	0.928	4.05	0.077	2.52	0.919	2.52	0.919	6.0	0.005
0.169	0.657	1.75	0.922	4.19	0.047	2.84	0.919	2.84	0.919	6.5	0.005
0.171	0.746	1.84	0.914	4.39	0.000	3.00	0.899	3.00	0.899	7.0	0.005
0.173	0.792	1.93	0.903			3.14	0.881	3.14	0.881	7.5	0.005
0.175	0.817	1.98	0.888			3.49	0.881	3.37	0.872	8.0	0.005
0.178	0.832	2.00	0.892			3.61	0.799	3.52	0.852	8.5	0.005
0.184	0.852	2.02	0.871			3.72	0.697	3.67	0.721	9.0	0.005
0.188	0.865	2.06	0.846			3.77	0.620	3.80	0.530	9.5	0.005
0.197	0.880	2.08	0.816			3.83	0.063	3.83	0.490	10.0	0.005
0.204	0.890	2.14	0.701			3.86	0.562	3.90	0.459	10.5	0.005
0.211	0.898	2.17	0.635			3.94	0.562	4.00	0.437	11.0	0.005
0.215	0.900	2.20	0.600			4.00	0.552	4.11	0.352	11.5	0.005
0.220	0.908	2.24	0.624			4.02	0.549	4.19	0.248	12.0	0.005
0.230	0.915	2.33	0.754			4.16	0.403	4.31	0.224	12.5	0.005
0.236	0.918	2.40	0.841			4.22	0.318	4.35	0.136	13.0	0.005
0.242	0.923	2.43	0.850			4.28	0.308	4.39	0.377	13.5	0.005
0.246	0.924	2.47	0.840			4.33	0.201	4.47	0.052	14.0	0.005
0.252	0.927	2.53	0.703			4.37	0.130	4.71	0.031	14.5	0.005
0.266	0.932	2.55	0.654			4.48	0.084	4.78	0.000	15.0	0.005
0.281	0.932	2.61	0.335			4.60	0.100	5.00	0.000	16.0	0.005
0.299	0.932	2.64	0.144			4.71	0.060	6.00	0.000		
0.339	0.933	2.65	0.100			4.76	0.028				
0.398	0.933	2.70	0.057			4.86	0.000				
0.493	0.934	2.77	0.042			5.00	0.000				
0.560	0.935	2.83	0.061			6.00	0.000				
0.743	0.937	2.89	0.102								
0.805	0.937	2.92	0.415								
1.00	0.933	2.93	0.689								
1.22	0.930	2.95	0.743								
1.27	0.921	3.00	0.776								
1.29	0.903	3.04	0.782								
1.31	0.882	3.10	0.773								
1.32	0.869	3.38	0.529								
1.34	0.859	3.66	0.304								
1.37	0.870	3.77	0.203								
1.41	0.898	3.80	0.182								
1.43	0.915	3.84	0.154								

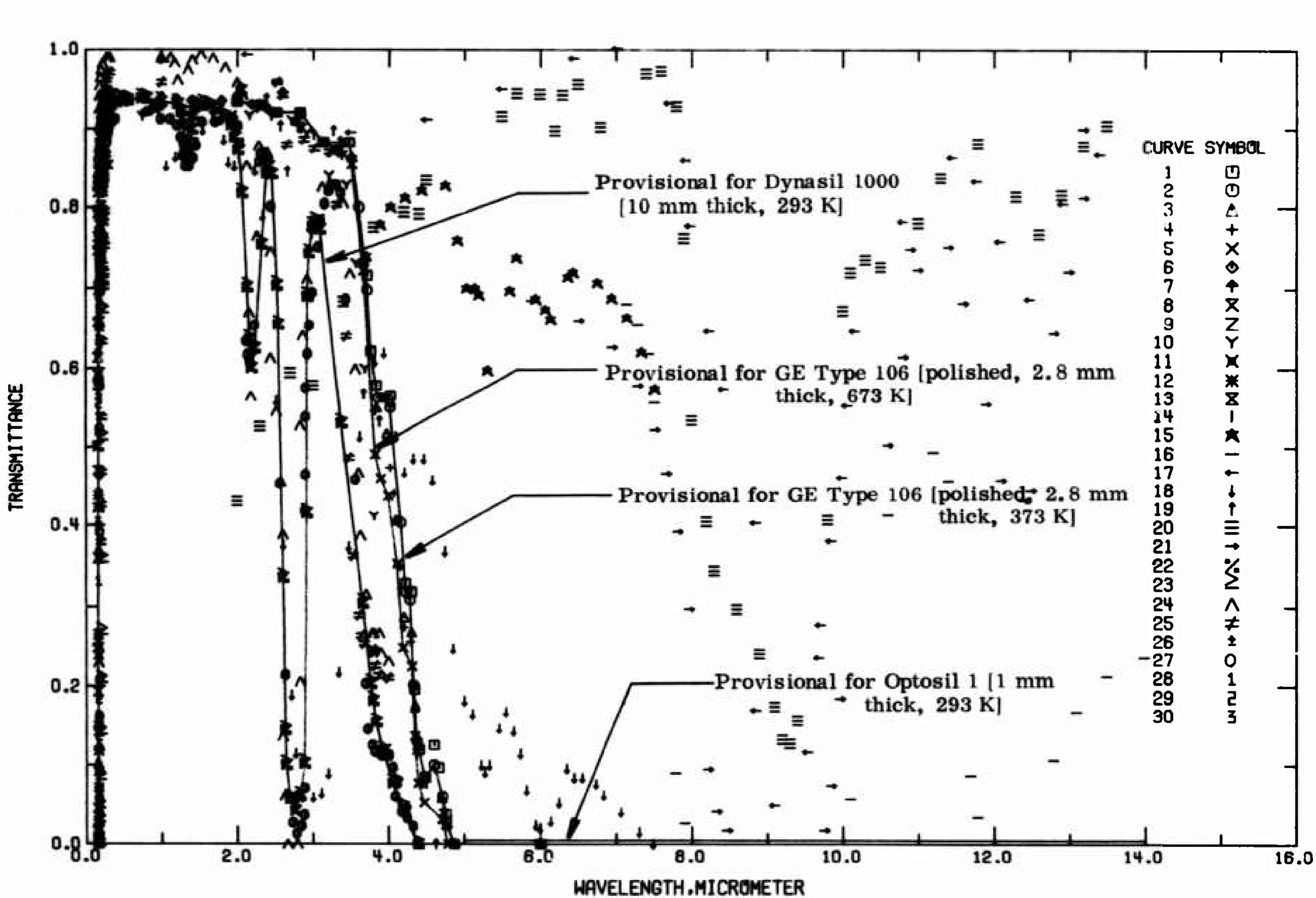


FIGURE 11-15. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

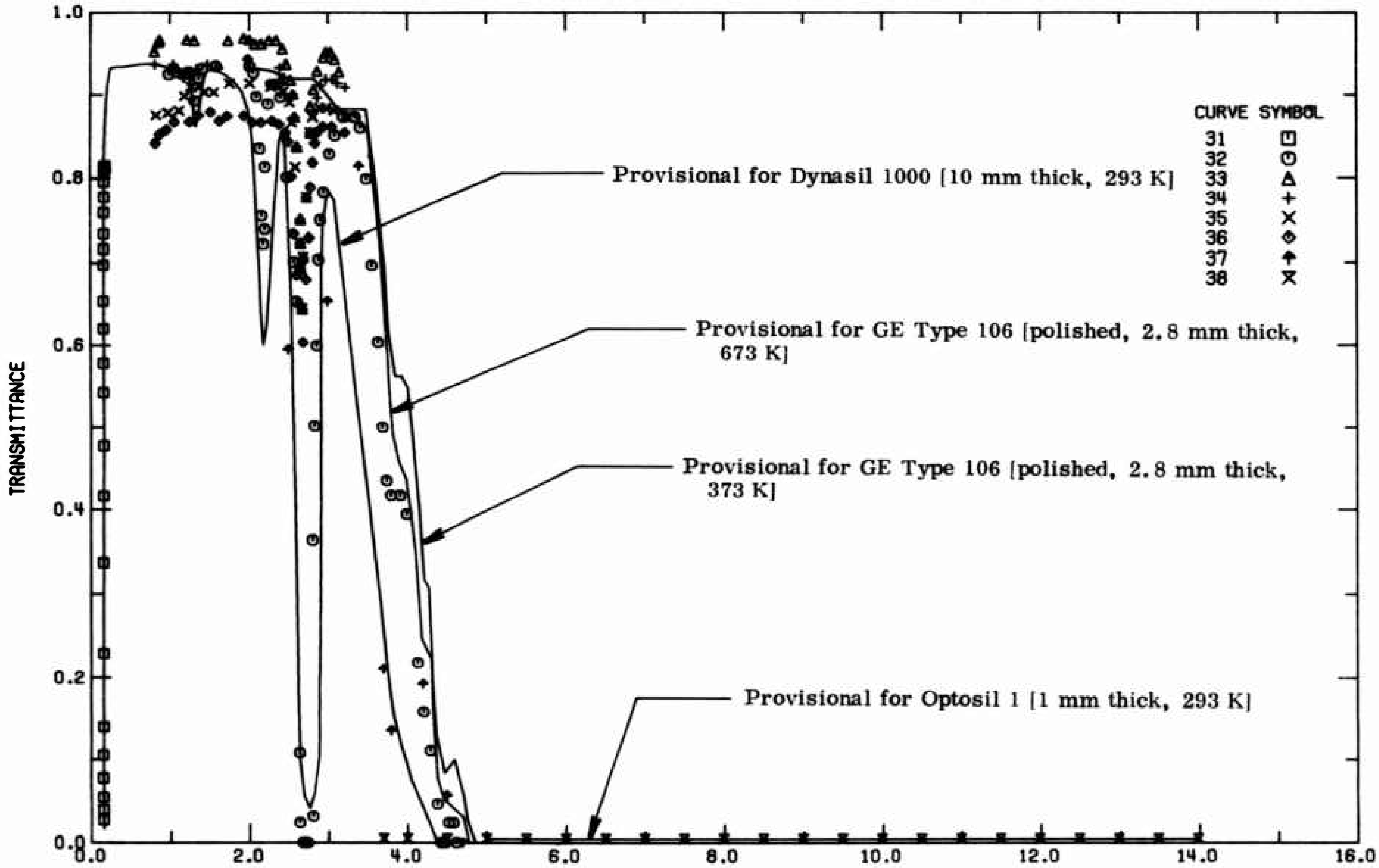


FIGURE 11-16. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

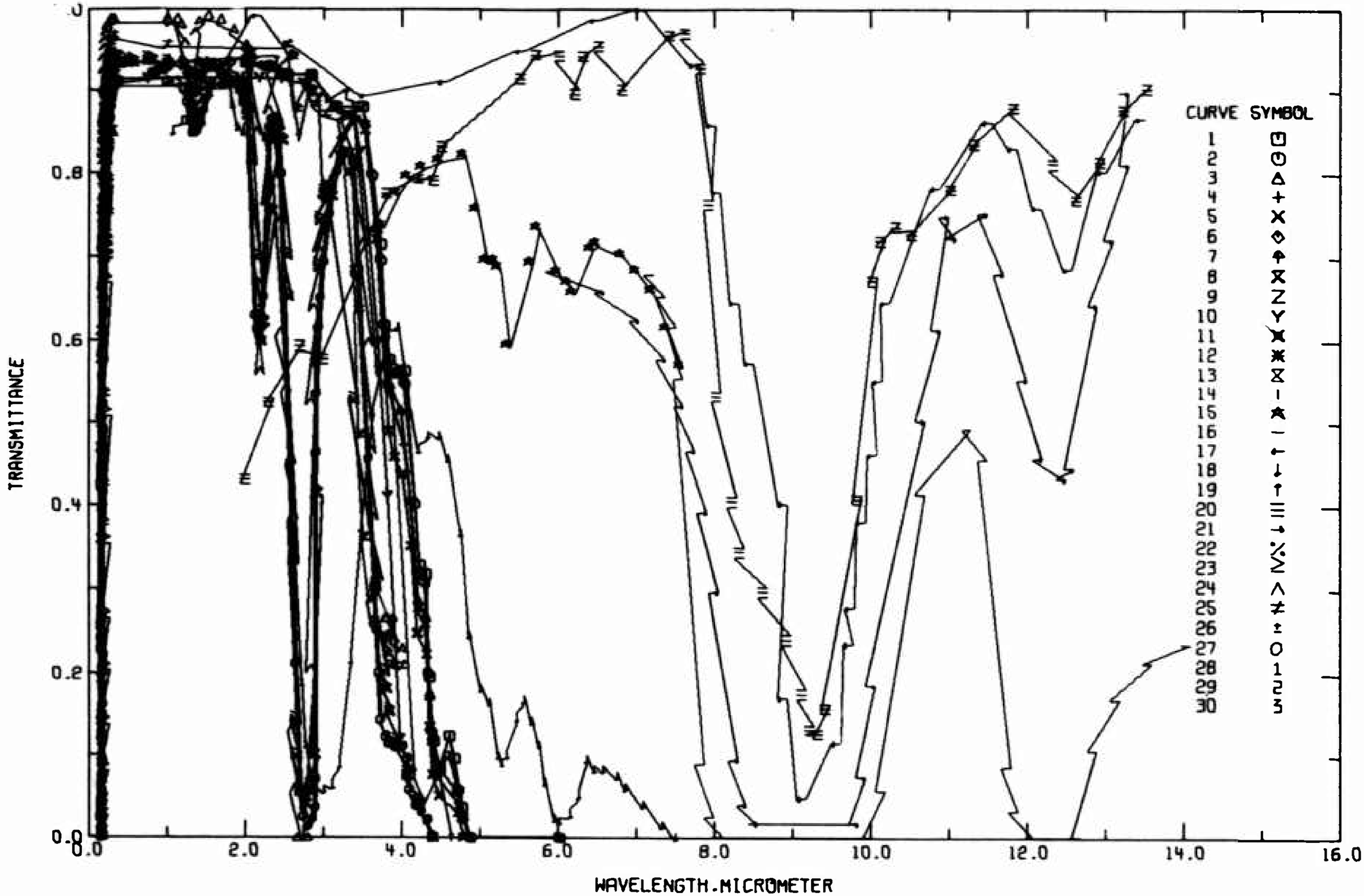


FIGURE 11-17. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

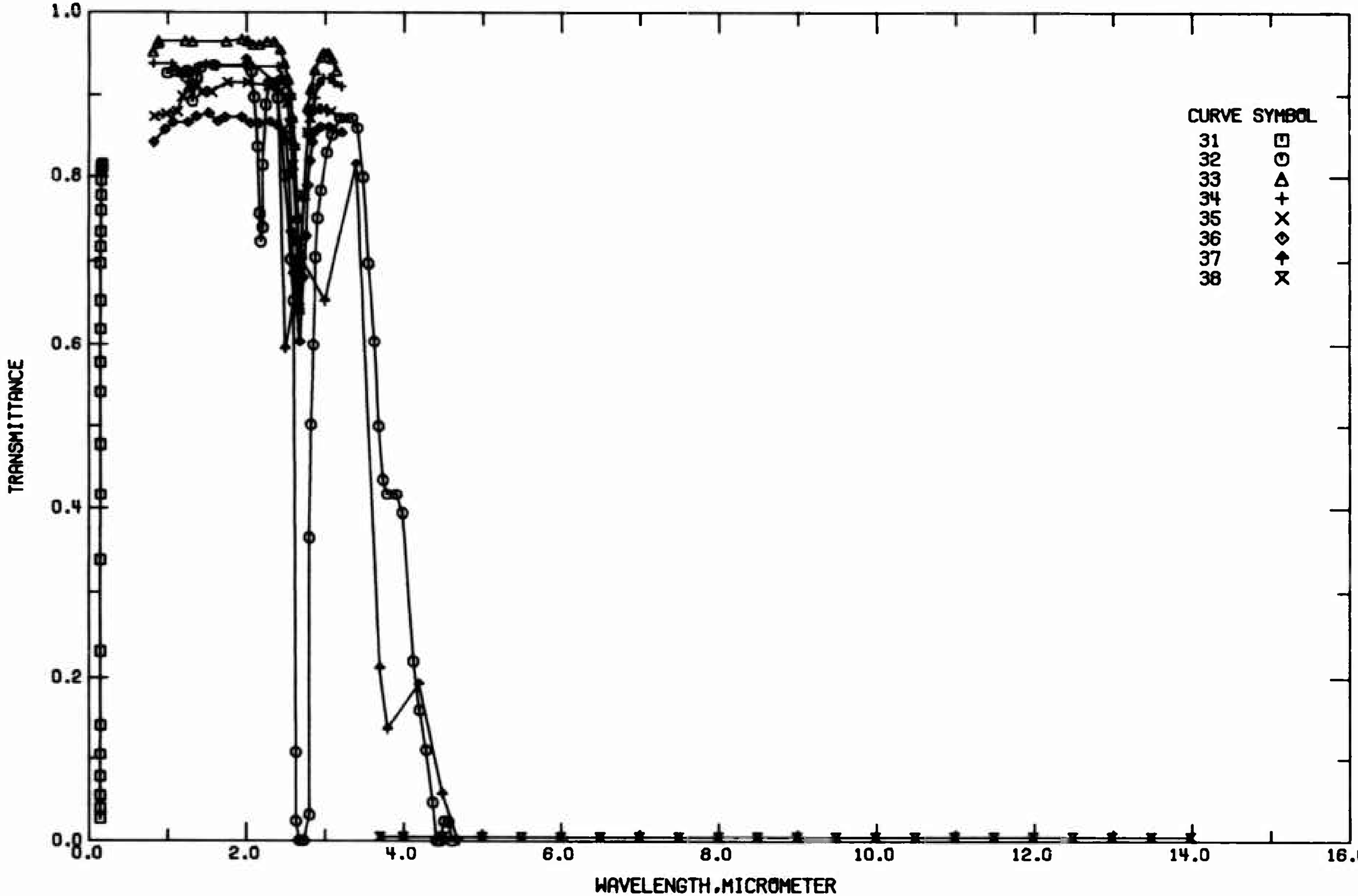


FIGURE 11-18. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE).

TABLE 11-23. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T38674	Gillespie, D.T., Olsen, A.L., and Nichols, L.W.	1965	2.0-6.0	298	Fused Quartz; GE Type 106	Disk specimen 3.150 cm in diameter and 2.8 mm thick; polished optically flat to within five green mercury fringes and a parallelism tolerance of ± 2.5 μm; smooth values from figure; Perkin-Elmer model 21 spectrophotometer used; $\theta=0°$, $\theta'=0°$.
2	T38674	Gillespie, D.T., et al.	1965	2.0-6.0	373	Fused Quartz; GE Type 106	The above specimen.
3	T38674	Gillespie, D.T., et al.	1965	2.0-6.0	473	Fused Quartz; GE Type 106	The above specimen.
4	T38674	Gillespie, D.T., et al.	1965	2.0-6.0	573	Fused Quartz; GE Type 106	The above specimen.
5	T38674	Gillespie, D.T., et al.	1965	2.0-6.0	673	Fused Quartz; GE Type 106	The above specimen.
6	T27141	Bogdan, L.	1964	0.80-2.6	293	Fused Quartz	Disk specimen 0.375 in. in diameter and 0.0625 in. thick; clear fused quartz blank; data from figure; measurement temperature not given explicitly, assumed to be 293 K; $\theta=0°$, $\theta'=0°$.
7	T33965	Laulainen, N.S. and McDermott, M.N.	1966	0.19-0.30	293	Fused Silica; Suprasil II	Two 0.0625 in. disks with an air space in between disks; measurements made with Cary model 14 spectrophotometer; measurement temperature not given explicitly, assumed to be 293 K; $\theta=0°$, $\theta'=0°$.
8	T33965	Laulainen, N.S. and McDermott, M.N.	1966	0.19-0.30	293	Fused Silica; Suprasil II	Similar to the above specimen except cemented by 0.0002 in. thick d-xylose obtained from Difco Labs, Detroit.
9	T45017	Sviridova, A.A. and Suikovskaya, N.V.	1967	0.19-0.42	293	Fused Quartz	Specimen 35 mm in diameter and 2 mm thick; surfaces plane-parallel; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; $\theta=0°$, $\theta'=0°$.
10	T54663	Calingaert, G., Heron, S.D., and Stair, R.	1936	0.21-4.0	293	Quartz	Synthetic fused quartz; amorphous; cylindrical specimen approx. 5/8 in. in diameter and 5/16 in. thick; two flat surfaces polished; measurement temperature not given explicitly, assumed to be 293 K; $\theta\sim0°$, $\theta'\sim0°$.
11	T39011	Heath, D.F. and Sacher, P.A.	1966	0.16-0.30	293	Fused Silica; Dynasil Optical Grade	High purity; specimen 6.46 mm thick; measured with aid of McPherson Model 225 monochromator; possibly measured in vacuum; data from figure; measurement temperature not given explicitly, assumed to be 293 K; $\theta=0°$, $\theta'=0°$.
12	T39011	Heath, D.F. and Sacher, P.A.	1966	0.16-0.30	293	Fused Silica; Dynasil Optical Grade	The above specimen except irradiated with 10^{14} electrons cm^{-2} at 1.0 MeV and then 10^{14} electrons cm^{-2} at 2.0 MeV, irradiation times 30 min at each energy.
13	T39011	Heath, D.F. and Sacher, P.A.	1966	0.16-0.30	293	Fused Silica; Dynasil 1850 A	Specimen 2.04 mm thick; data from figure; possibly measured in vacuum; measurement temperature not given explicitly, assumed to be 293 K; $\theta=0°$, $\theta'=0°$.
14	T39011	Heath, D.F. and Sacher, P.A.	1966	0.16-0.30	293	Fused Silica; Dynasil 1850 A	The above specimen except irradiated with 10^{14} electrons cm^{-2} at 2.0 MeV incident through a sapphire shield, 6.4 mm thick.
15	T38719	Hanna, R.	1965	3.7-7.5	293	Fused Silica	Specimen $22 \pm 2 \times 10^{-3}$ mm thick; cut and ground but not polished; smooth values from figure; Perkin-Elmer model 13U instrument used below 15 μm and above Perkin-Elmer model 201 spectrophotometer used; measurement temperature not given explicitly, assumed to be 293 K; $\theta=0°$, $\theta'=0°$.
16	T38719	Hanna, R.	1965	7.1-20	293	Fused Silica	The above specimen.
17	T30490	Howarth, L.E. and Spitzer, W.G.	1961	1.0-30	293	Vitreous Silica	Specimen 6500 Å thick; Perkin-Elmer single-beam double-pass spectrometer used; measurement temperature not given explicitly, assumed to be 293 K; $\theta=0°$, $\theta'=0°$.

TABLE 11-23. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF SILICA (VITREOUS) (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
18	T51607	Coblentz, M.W.	1906	1.1-7.5	293	Opal	$SiO_2 + XH_2O$ (opal contains varying amount of water from 5 to 30%); massive; transparent; thickness 0.12 mm; measurement temperature not given explicitly, assumed to be 293 K; θ=0°, θ'=0°.
19	T35036	Grenis, A.F. and Matkovich, M.J.	1965	1.0-4.6	293	Fused Silica	Specimen approx. 5.08 cm in diameter and 3.18 mm thick; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; θ=0°, θ'=0°.
20	T43741	Bartlet, R.W. and Gage, P.R.	1964	2.0-15	293	Silica Gel	Smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; θ=0°, θ'=0°.
21	T34168	Engelsrath, A.	1965	5.9-39	293	Fused Quartz	50 mg crushed fused quartz in 2 gm polyethylene binder; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; θ=0°, θ'=0°.
22	T77041	Dynasil Corporation of America	1973	0.16-4.4	293	Dynasil 1000 Fused Silica	Typical analysis has total metallic impurity content approx. 0.0001-0.0002, water content approx. 0.06-0.1, 0.00885 Cl, <0.0001 B, 0.000020 Fe, 0.000020 Li, <0.000008 Cd, <0.000006 Ge, <0.000005 Tl, <0.000004 Bi, <0.000003 Be, <0.000002 Al, <0.000002 Ga, 0.000002 Na, 0.0000006 Cr, 0.00000025 Br, 0.0000001 Au, 0.000001 Co, 0.00000004 Sb, and the following not detected, As, Cs, Cu, Mn, Rb, Ag, Ti, V, and Zn; specimen thickness 10 mm; smooth values from figure; temperature not given explicitly, presumed to be room temperature, 293 K assigned; reflection losses are included.
23	T77041	Dynasil Corporation of America	1973	0.18-4.4	293	Dynasil 4000 Fused Silica	Similar to the above specimen.
24	A00010	Thermal American Fused Quartz Co.		0.17-4.0	293	Spectrosil Synthetic Fused Quartz	<0.00001 Ca, <0.00001 Fe, 0.000004 Na, <0.000002 Al, <0.000001 B, <0.0000004 Ga, <0.0000004 K, <0.0000001 P, <0.0000001 Mn, <0.00000002 As, <0.00000002 Cu, and 0.00000001 Sb (see Hetherington, G. and Bell, L.W., "Analysis of High-Purity Synthetic Vitreous Silicas," Physics and Chemistry of Glasses, 8(3), 206-8, 1967, [A00011]); 10 mm path; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K.
25	A00010	Thermal American Fused Quartz Co.		0.20-4.0	293	Vitreosil I.R.	99.8+ SiO_2; 10 mm path; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K.
26	T75891	Corning Glass Works	1971	0.16-4.4	293	Corning Code 7940 Fused Silica	Typical analysis 0.0010-0.0100 Cl, 0.00001-0.0001 Ca, 0.00001-0.0010 Ti, 0.000005-0.0005 Al, 0.000005-0.00005 Be, 0.000005-0.00005 Zn, 0.000001-0.00001 Bi, 0.000001-0.000005 Cu, 0.000001-0.0005 Fe, 0.000001-0.00001 K, 0.000001-0.00001 Mg, 0.000001-0.0001 Na, 0.000001-0.00001 P, 0.000001-0.00001 V, 0.0000001-0.0000005 As, 0.0000001-0.000005 Cr, 0.0000001-0.000001 Mn, and 0.0000001-0.0000005 Sb, maximum total impurities other than water do not exceed 0.01, water content estimated at 0.1 or less; amorphous, made by flame hydrolysis; specimen 10 mm thick; minimum transmittance for U.V. grades; surface reflections included; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K.
27	T76891	Corning Glass Works	1971	0.18-4.4	293	Corning Code 7940 Fused Silica	Similar to the above specimen except minimum transmittance values for optical and industrial grades.
28	T76891	Corning Glass Works	1971	0.16-0.19	293	Corning Code 7940 Fused Silica	Same typical analysis, impurity content, and method of fabrication as above; specimen 10 mm thick; U.V. grade; surface reflections included smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K.
29	T76891	Corning Glass Works	1971	0.16-0.18	293	Corning Code 7940 Fused Silica	Similar to the above specimen except 5 mm thick.

TABLE 11-23. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
30	T76891	Corning Glass Works	1971	0.15–0.19	293	Corning Code 7940 Fused Silica	Similar to the above specimen except 1 mm thick.
31	T76891	Corning Glass Works	1971	0.15–0.19	293	Corning Code 7940 Fused Silica	Similar to the above specimen except 0.5 mm thick.
32	T76891	Corning Glass Works	1971	1.0–4.6	298	Corning Code 7940 Fused Silica	Same typical analysis, impurity content, and method of fabrication as above; specimen 5.0 mm thick.
33	T31344	Kroeckel, O.	1964	0.82–3.2	293	Quartz Glass	Smooth values from figure; relative error in transmission of 3.5%; $\theta=0°$, $\theta'=0°$.
34	T31344	Kroeckel, O.	1964	0.83–3.2	773	Quartz Glass	Similar to the above specimen.
35	T31344	Kroeckel, O.	1964	0.84–3.2	973	Quartz Glass	Similar to the above specimen.
36	T31344	Kroeckel, O.	1964	0.83–3.2	1173	Quartz Glass	Similar to the above specimen.
37	T30100	McCarthy, D.E.	1963	2.0–50	293	Quartz	Synthetic; specimen 2 mm thick; ground and polished to a flatness of seven fringes or better; reference standard was aluminum mirror; smooth values from figure; measurement temperature not given explicitly, assumed to be 293 K; Beckman IR-5A used in 2–16 μm range and Beckman IR-7 with CsI interchange used in 12.5–50 μm range; $\theta=0°$, $\theta'=0°$.
38	A00012	Champetier, R.J. and Friese, G.J.	1974	3.7–16	293	Optosil 1 Fused Silica	Specimen 1 mm thick; measured at Aerospace Corporation's Material Sciences Laboratory; measurement temperature not given explicitly, assumed to be 293 K; complete opacity (<0.005 transmittance from 3.7 to at least 16 μm); $\theta\sim0°$, $\theta'\sim0°$.

TABLE 11-24. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 1	
T = 298.	
2.00	0.933
2.31	0.928
2.53	0.919
2.84	0.919
3.15	0.881
3.49	0.881
3.72	0.715
3.77	0.620
3.84	0.578
4.03	0.565
4.22	0.328
4.30	0.318
4.34	0.196
4.40	0.119
4.48	0.085
4.60	0.125
4.66	0.097
4.76	0.035
4.86	0.000
6.00	0.000
CURVE 2	
T = 373.	
2.00	0.933
2.30	0.929
2.52	0.919
2.84	0.919
3.14	0.881
3.49	0.881
3.61	0.799
3.72	0.697
3.77	0.620
3.86	0.562
3.94	0.562
4.02	0.549
4.16	0.403
4.22	0.318
4.28	0.308

λ	τ
CURVE 2(CONT.)	
4.33	0.201
4.37	0.130
4.48	0.084
4.60	0.100
4.71	0.060
4.76	0.028
4.86	0.000
6.00	0.000
CURVE 3	
T = 473.	
2.00	0.933
2.31	0.928
2.52	0.919
2.84	0.919
3.14	0.881
3.52	0.862
3.68	0.734
3.84	0.549
3.98	0.516
4.10	0.406
4.20	0.287
4.30	0.268
4.35	0.176
4.38	0.124
4.48	0.084
4.70	0.058
4.76	0.024
4.86	0.000
6.00	0.000
CURVE 4	
T = 573.	
2.00	0.933
2.31	0.928
2.52	0.919
2.84	0.919
3.14	0.881

λ	τ
CURVE 4(CONT.)	
3.52	0.863
3.68	0.734
3.82	0.544
4.02	0.473
4.07	0.440
4.15	0.349
4.20	0.274
4.29	0.256
4.34	0.168
4.37	0.114
4.44	0.076
4.72	0.043
4.78	0.022
4.86	0.000
6.00	0.000
CURVE 5	
T = 673.	
2.00	0.933
2.30	0.928
2.52	0.919
2.64	0.919
3.14	0.881
3.37	0.872
3.52	0.852
3.67	0.721
3.83	0.490
3.90	0.459
4.00	0.437
4.11	0.352
4.19	0.248
4.31	0.224
4.35	0.136
4.39	0.077
4.47	0.052
4.71	0.031
4.78	0.000
5.00	0.000

λ	τ
CURVE 6	
T = 293.	
0.800	0.920
0.850	0.921
0.900	0.926
0.950	0.924
1.00	0.928
1.20	0.936
1.40	0.934
1.60	0.929
1.80	0.934
2.00	0.939
2.20	0.929
2.40	0.925
2.60	0.944
CURVE 7	
T = 293.	
0.193	0.695
0.203	0.768
0.210	0.831
0.220	0.864
0.250	0.887
0.300	0.909
CURVE 8	
T = 293.	
0.193	0.739
0.200	0.761
0.210	0.800
0.220	0.817
0.250	0.840
0.300	0.851
CURVE 9	
T = 293.	
0.191	0.777
0.216	0.889

λ	τ
CURVE 9(CONT.)	
0.243	0.921
0.291	0.942
0.358	0.942
0.418	0.939
CURVE 10	
T = 293.	
0.310	0.912
0.750	0.914
1.26	0.915
1.69	0.915
1.93	0.915
2.17	0.915
2.46	0.914
2.73	0.909
2.85	0.899
2.93	0.893
2.98	0.767
3.09	0.785
3.22	0.838
3.39	0.864
3.45	0.826
3.57	0.730
3.69	0.599
3.81	0.411
3.97	0.121
CURVE 11	
T = 293.	
0.1601	0.000
0.1612	0.008
0.1620	0.018
0.1628	0.045
0.1636	0.091
0.1639	0.117
0.1641	0.141
0.1652	0.238
0.1671	0.421

λ	τ
CURVE 11(CONT.)	
0.1697	0.591
0.1748	0.696
0.1795	0.769
0.1849	0.795
0.1896	0.817
0.1946	0.837
0.1997	0.846
0.2045	0.867
0.2097	0.877
0.2148	0.886
0.2196	0.901
0.2247	0.907
0.2298	0.924
0.2348	0.939
0.2400	0.929
0.2449	0.936
0.2497	0.933
0.2550	0.941
0.2598	0.928
0.2649	0.934
0.2697	0.945
0.2748	0.932
0.2798	0.936
0.2848	0.935
0.2898	0.942
0.2949	0.941
0.3000	0.942
CURVE 12	
T = 293.	
0.1601	0.000
0.1614	0.002
0.1628	0.029
0.1641	0.071
0.1652	0.148
0.1667	0.265
0.1699	0.437
0.1748	0.584
0.1799	0.650

TABLE 11-24. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ
CURVE 12(CONT.)	
0.1848	0.698
0.1897	0.725
0.1948	0.738
0.1997	0.749
0.2046	0.735
0.2097	0.740
0.2146	0.750
0.2197	0.756
0.2247	0.784
0.2298	0.793
0.2347	0.817
0.2396	0.841
0.2448	0.855
0.2498	0.869
0.2549	0.888
0.2599	0.890
0.2648	0.891
0.2697	0.913
0.2748	0.916
0.2799	0.930
0.2848	0.928
0.2899	0.929
0.2951	0.925
0.3000	0.929
CURVE 13	
T = 293.	
0.1595	0.004
0.1607	0.044
0.1631	0.193
0.1647	0.359
0.1656	0.469
0.1667	0.578
0.1667	0.612
0.1701	0.763
0.1749	0.824
0.1803	0.845
0.1850	0.853
0.1901	0.855

λ	τ
CURVE 13(CONT.)	
0.1952	0.861
0.1999	0.872
0.2053	0.875
0.2102	0.886
0.2150	0.899
0.2200	0.955
0.2249	0.903
0.2300	0.912
0.2350	0.912
0.2400	0.908
0.2453	0.921
0.2500	0.918
0.2550	0.928
0.2600	0.936
0.2648	0.939
0.2704	0.940
0.2751	0.942
0.2796	0.928
0.2850	0.929
0.2902	0.937
0.2946	0.942
0.3000	0.927
CURVE 14	
T = 293.	
0.1599	0.011
0.2200	0.909
0.1606	0.045
0.1631	0.193
0.1649	0.359
0.1667	0.580
0.1667	0.612
0.1702	0.762
0.1750	0.849
0.1799	0.869
0.1850	0.875
0.1904	0.881
0.1951	0.886
0.1999	0.890

λ	τ
CURVE 14(CONT.)	
0.2051	0.894
0.2100	0.902
0.2143	0.909
0.2250	0.901
0.2301	0.910
0.2351	0.922
0.2399	0.914
0.2450	0.921
0.2498	0.919
0.2550	0.927
0.2599	0.923
0.2649	0.923
0.2701	0.927
0.2752	0.924
0.2799	0.927
0.2853	0.929
0.2902	0.929
0.2948	0.926
0.3000	0.907
CURVE 15	
T = 293.	
3.70	0.739
3.89	0.778
4.03	0.799
4.22	0.810
4.44	0.819
4.75	0.825
4.91	0.759
5.03	0.699
5.14	0.699
5.19	0.691
5.31	0.597
5.60	0.696
5.69	0.737
5.94	0.686
6.07	0.673
6.14	0.661
6.37	0.713

λ	τ
CURVE 15(CONT.)	
6.44	0.719
6.76	0.706
6.95	0.687
7.15	0.663
7.34	0.619
7.52	0.574
CURVE 16	
T = 293.	
7.14	0.680
7.29	0.654
7.43	0.617
7.51	0.556
7.79	0.090
7.91	0.026
8.04	0.000
9.94	0.000
10.1	0.057
10.6	0.413
11.2	0.493
11.4	0.456
11.7	0.087
11.8	0.034
12.0	0.000
12.6	0.000
12.8	0.106
13.1	0.168
13.5	0.212
14.0	0.236
14.7	0.245
15.5	0.229
16.9	0.158
18.2	0.075
19.5	0.000
CURVE 17	
T = 293.	
1.03	0.983

λ	τ
CURVE 17(CONT.)	
1.40	0.886
2.13	0.992
2.53	0.956
3.51	0.894
4.51	0.910
5.50	0.948
6.45	0.987
7.02	1.00
7.71	0.931
7.93	0.858
7.99	0.777
8.23	0.646
8.42	0.574
8.85	0.403
8.85	0.170
9.10	0.049
9.54	0.116
9.69	0.236
9.71	0.278
9.85	0.380
9.99	0.461
10.06	0.552
10.16	0.646
10.80	0.782
11.46	0.862
11.78	0.831
12.09	0.758
12.48	0.686
12.92	0.803
13.41	0.866
14.47	0.908
16.37	0.911
17.37	0.895
18.85	0.878
19.61	0.853
19.92	0.807
20.23	0.706
20.47	0.608
20.76	0.544
20.96	0.453

λ	τ
CURVE 17(CONT.)	
21.20	0.338
21.38	0.284
21.65	0.235
22.36	0.276
22.87	0.360
23.43	0.456
24.42	0.580
25.04	0.644
25.89	0.730
26.98	0.786
27.55	0.811
28.35	0.840
29.04	0.861
30.42	0.895
CURVE 18	
T = 293.	
1.07	0.850
1.19	0.862
1.32	0.874
1.40	0.869
1.48	0.880
1.55	0.897
1.68	0.910
1.79	0.910
1.83	0.884
1.89	0.855
1.97	0.850
2.08	0.880
2.24	0.844
2.34	0.789
2.52	0.558
2.61	0.375
2.72	0.189
2.77	0.114
2.86	0.059
3.00	0.059
3.11	0.064
3.20	0.089

TABLE 11-24. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 18(CONT.)	
3.34	0.217
3.47	0.373
3.62	0.512
3.82	0.608
3.94	0.619
4.06	0.556
4.10	0.512
4.21	0.467
4.33	0.485
4.47	0.485
4.58	0.457
4.74	0.367
4.85	0.247
5.00	0.182
5.11	0.165
5.22	0.100
5.27	0.091
5.33	0.100
5.46	0.146
5.55	0.168
5.65	0.143
5.74	0.114
5.82	0.068
5.94	0.024
6.00	0.020
6.14	0.029
6.25	0.052
6.35	0.096
6.45	0.084
6.56	0.084
6.74	0.076
6.84	0.062
7.07	0.041
7.31	0.015
7.49	0.000
CURVE 19	
T = 293.	
1.00	0.938

λ	τ
CURVE 19(CONT.)	
2.39	0.936
2.58	0.902
2.67	0.843
2.81	0.900
3.02	0.891
3.28	0.896
3.37	0.882
3.67	0.567
3.88	0.531
4.15	0.079
4.26	0.043
4.49	0.077
4.62	0.000
CURVE 20	
T = 293.	
2.0	0.430
2.3	0.525
2.7	0.594
3.0	0.578
3.4	0.683
3.8	0.775
4.2	0.793
4.4	0.791
4.5	0.832
5.5	0.914
5.7	0.943
6.0	0.942
6.2	0.896
6.3	0.941
6.5	0.954
6.8	0.901
7.4	0.968
7.6	0.971
7.8	0.927
7.9	0.762
8.0	0.533
8.2	0.405
8.3	0.344

λ	τ
CURVE 20(CONT.)	
8.6	0.297
8.9	0.241
9.1	0.175
9.2	0.132
9.3	0.127
9.4	0.157
9.8	0.407
10.0	0.672
10.1	0.719
10.3	0.735
10.5	0.726
11.0	0.780
11.3	0.835
11.8	0.880
12.3	0.812
12.6	0.767
12.9	0.814
13.2	0.877
13.5	0.903
14.5	0.901
14.9	0.878
15.1	0.827
15.2	0.847
CURVE 21	
T = 293.	
5.88	0.684
6.51	0.659
6.95	0.625
7.29	0.576
7.52	0.521
7.67	0.466
7.82	0.392
7.97	0.297
8.22	0.095
8.33	0.041
8.47	0.017
9.76	0.017
9.85	0.074

λ	τ
CURVE 21(CONT.)	
9.97	0.185
10.6	0.502
10.8	0.613
10.9	0.748
11.0	0.722
11.4	0.751
11.6	0.681
11.9	0.554
12.1	0.457
12.4	0.431
12.5	0.444
12.8	0.643
13.0	0.720
13.2	0.810
13.2	0.898
15.1	0.800
17.2	0.685
18.5	0.597
19.5	0.467
19.9	0.348
20.2	0.099
20.4	0.013
21.4	0.013
22.1	0.065
23.0	0.202
28.2	0.822
29.6	0.839
34.5	0.863
39.1	0.863
CURVE 22	
T = 293.	
0.157	0.017
0.160	0.248
0.166	0.500
0.159	0.657
0.171	0.746
0.173	0.792
0.175	0.817

λ	τ
CURVE 22(CONT.)	
0.178	0.832
0.184	0.852
0.188	0.865
0.197	0.880
0.204	0.890
0.211	0.898
0.215	0.900
0.220	0.908
0.230	0.915
0.236	0.918
0.242	0.923
0.246	0.924
0.252	0.927
0.266	0.932
0.281	0.932
0.299	0.932
0.339	0.933
0.398	0.933
0.493	0.934
0.560	0.935
0.743	0.937
0.805	0.337
1.00	0.933
1.22	0.930
1.27	0.921
1.29	0.903
1.31	0.882
1.32	0.869
1.34	0.859
1.37	0.870
1.41	0.898
1.43	0.915
1.48	0.928
1.55	0.930
1.64	0.928
1.75	0.922
1.84	0.914
1.93	0.903
1.98	0.888
2.02	0.871

λ	τ
CURVE 22(CONT.)	
2.06	0.946
2.08	0.816
2.14	0.701
2.17	0.635
2.20	0.600
2.24	0.624
2.33	0.754
2.40	0.841
2.43	0.850
2.47	0.840
2.53	0.703
2.55	0.654
2.61	0.335
2.64	0.144
2.65	0.100
2.70	0.057
2.77	0.042
2.83	0.061
2.89	0.102
2.92	0.415
2.93	0.689
2.95	0.743
3.00	0.776
3.04	0.782
3.10	0.773
3.38	0.529
3.66	0.304
3.77	0.203
3.80	0.182
3.84	0.154
3.93	0.118
4.06	0.077
4.19	0.047
4.39	0.008
CURVE 23	
T = 293.	
0.178	0.000
0.184	0.030

TABLE 11-24. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA (VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

CURVE 23 (CONT.)

λ	τ
0.188	0.048
0.197	0.084
0.204	0.141
0.211	0.207
0.216	0.269
0.221	0.357
0.230	0.511
0.236	0.672
0.242	0.787
0.246	0.834
0.252	0.871
0.266	0.896
0.281	0.913
0.296	0.922
0.339	0.926
0.398	0.931
0.493	0.934
0.560	0.935
0.743	0.937
0.805	0.937
1.00	0.933
1.22	0.930
1.27	0.921
1.29	0.903
1.31	0.882
1.32	0.869
1.34	0.859
1.37	0.870
1.41	0.898
1.43	0.915
1.48	0.928
1.55	0.930
1.64	0.928
1.75	0.922
1.84	0.914
1.93	0.903
1.98	0.888
2.02	0.871
2.06	0.946
2.08	0.815
2.14	0.701
2.17	0.635
2.20	0.600
2.24	0.624
2.33	0.754
2.40	0.841
2.43	0.850
2.47	0.840
2.53	0.703
2.55	0.654
2.61	0.335
2.64	0.144
2.65	0.100
2.70	0.057
2.77	0.042
2.83	0.061
2.89	0.102
2.92	0.415
2.93	0.689
2.95	0.743
3.00	0.776
3.04	0.782
3.10	0.773
3.38	0.529
3.66	0.304
3.77	0.203
3.80	0.182
3.84	0.154
3.93	0.118
4.06	0.077
4.19	0.047
4.39	0.000

CURVE 24
T = 293.

λ	τ
0.165	0.123
0.165	0.229
0.168	0.423
0.174	0.711
0.177	0.865
0.179	0.932
0.181	0.924
0.183	0.940
0.189	0.953
0.195	0.963
0.207	0.973
0.227	0.981
0.279	0.989
0.320	0.989
1.000	0.989
1.126	0.989
1.177	0.982
1.217	0.960
1.330	0.867
1.351	0.973
1.407	0.996
1.523	0.993
1.682	0.988
1.845	0.976
2.001	0.957
2.072	0.942
2.136	0.851
2.158	0.670
2.184	0.564
2.261	0.765
2.293	0.877
2.327	0.925
2.403	0.868
2.445	0.745
2.445	0.612
2.517	0.544
2.575	0.455
2.601	0.339
2.601	0.136
2.629	0.061
2.661	0.008
2.789	0.000
2.831	0.206
2.931	0.526
2.866	0.640
2.922	0.711
3.026	0.775
3.130	0.824
3.283	0.868
3.402	0.804
3.491	0.718
3.563	0.599
3.602	0.467
3.626	0.387
3.699	0.315
3.778	0.267
3.874	0.267
3.897	0.242
4.000	0.231
3.800	0.267

CURVE 25
T = 293.

λ	τ
0.201	0.378
0.205	0.425
0.208	0.467
0.211	0.536
0.215	0.632
0.219	0.728
0.222	0.764
0.225	0.781
0.229	0.781
0.232	0.760
0.238	0.710
0.239	0.701
0.242	0.701
0.245	0.719
0.248	0.752
0.250	0.794
0.255	0.859
0.257	0.901
0.261	0.923
0.267	0.943
0.275	0.954
0.286	0.964
0.304	0.969
0.320	0.969
1.000	0.957
2.535	0.957
2.605	0.941
2.666	0.878
2.785	0.909
2.818	0.909
2.892	0.885
3.025	0.873
3.231	0.869
3.318	0.802
3.446	0.639
3.478	0.486
3.531	0.362
3.605	0.289
3.637	0.264
3.679	0.254
3.795	0.246
3.820	0.225
3.873	0.213
4.000	0.210
3.800	0.242

CURVE 26
T = 293.

λ	τ
0.160	0.000
0.162	0.100
0.165	0.251
0.167	0.367
0.167	0.519
0.169	0.585
0.172	0.636
0.176	0.677
0.181	0.718
0.187	0.755
0.193	0.784
0.201	0.816
0.209	0.840
0.220	0.869
0.230	0.883
0.240	0.895
0.251	0.906
0.261	0.909
0.330	0.911
0.398	0.911
1.000	0.911
1.128	0.911
1.215	0.903
1.267	0.888
1.300	0.864
1.333	0.850
1.385	0.850
1.437	0.860
1.471	0.877
1.551	0.907
1.727	0.907
1.968	0.911
2.028	0.902
2.134	0.633
2.157	0.616
2.184	0.609
2.218	0.619
2.242	0.653
2.313	0.856
2.336	0.867
2.389	0.867
2.439	0.857
2.463	0.800
2.580	0.453
2.652	0.214
2.718	0.057
2.745	0.027
2.799	0.013
2.863	0.023
2.898	0.037
2.908	0.071

TABLE 11-24. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ
CURVE 26(CONT.)	
2.512	0.418
2.914	0.464
2.916	0.537
2.919	0.575
2.943	0.617
2.964	0.653
3.006	0.694
3.078	0.751
3.117	0.783
3.171	0.803
3.228	0.819
3.259	0.826
3.327	0.826
3.384	0.816
3.450	0.686
3.577	0.458
3.709	0.203
3.734	0.145
3.800	0.125
3.833	0.117
3.918	0.112
4.019	0.112
4.071	0.097
4.097	0.082
4.097	0.060
4.182	0.041
4.256	0.033
4.335	0.022
4.400	0.000
CURVE 27	
T = 293.	
0.178	0.000
0.181	0.057
0.184	0.092
0.186	0.161
0.187	0.208
0.191	0.391
0.193	0.464

λ	τ
CURVE 27(CONT.)	
0.196	0.522
0.201	0.577
0.205	0.632
0.213	0.676
0.221	0.717
0.232	0.753
0.242	0.791
0.256	0.825
0.269	0.849
0.279	0.867
0.291	0.881
0.302	0.890
0.311	0.895
0.327	0.903
0.342	0.907
0.363	0.907
0.398	0.911
1.000	0.911
1.128	0.911
1.215	0.903
1.267	0.888
1.300	0.864
1.333	0.850
1.385	0.850
1.437	0.860
1.471	0.877
1.551	0.907
1.727	0.907
1.968	0.911
2.028	0.902
2.134	0.633
2.157	0.616
2.184	0.609
2.218	0.619
2.242	0.653
2.313	0.856
2.336	0.867
2.389	0.867
2.439	0.857
2.463	0.800

λ	τ
CURVE 27(CONT.)	
2.580	0.453
2.652	0.214
2.718	0.057
2.745	0.027
2.799	0.013
2.863	0.023
2.898	0.037
2.908	0.071
2.912	0.418
2.914	0.464
2.916	0.537
2.919	0.575
2.943	0.617
2.964	0.653
3.006	0.694
3.078	0.751
3.117	0.783
3.171	0.803
3.228	0.819
3.259	0.826
3.327	0.826
3.384	0.816
3.450	0.686
3.577	0.458
3.709	0.203
3.734	0.145
3.800	0.125
3.833	0.117
3.918	0.112
4.019	0.112
4.071	0.097
4.097	0.082
4.097	0.060
4.182	0.041
4.256	0.033
4.335	0.022
4.400	0.000

λ	τ
CURVE 28	
T = 293.	
0.1630	0.000
0.1614	0.015
0.1622	0.023
0.1630	0.034
0.1635	0.044
0.1643	0.071
0.1648	0.103
0.1668	0.246
0.1678	0.331
0.1686	0.399
0.1695	0.469
0.1704	0.511
0.1711	0.546
0.1717	0.571
0.1727	0.596
0.1737	0.618
0.1748	0.637
0.1759	0.653
0.1775	0.665
0.1789	0.677
0.1808	0.689
0.1824	0.700
0.1843	0.715
0.1860	0.730
0.1877	0.746
0.1900	0.767
CURVE 29	
T = 293.	
0.1600	0.019
0.1612	0.044
0.1623	0.068
0.1633	0.095
0.1641	0.136
0.1647	0.184
0.1657	0.266
0.1668	0.362
0.1676	0.439

λ	τ
CURVE 29(CONT.)	
0.1689	0.553
0.1696	0.622
0.1702	0.656
0.1713	0.679
0.1719	0.690
0.1732	0.708
0.1745	0.720
0.1757	0.728
0.1767	0.732
0.1783	0.735
0.1796	0.738
CURVE 30	
T = 293.	
0.1525	0.009
0.1536	0.014
0.1545	0.018
0.1554	0.027
0.1561	0.038
0.1571	0.055
0.1578	0.075
0.1583	0.097
0.1594	0.162
0.1607	0.252
0.1633	0.403
0.1665	0.566
0.1679	0.613
0.1693	0.670
0.1702	0.692
0.1710	0.708
0.1719	0.720
0.1730	0.732
0.1747	0.742
0.1776	0.748
0.1818	0.750
0.1843	0.750
0.1854	0.762
0.1865	0.771
0.1881	0.780

λ	τ
CURVE 30(CONT.)	
0.1900	0.782
CURVE 31	
T = 293.	
0.1530	0.027
0.1538	0.040
0.1546	0.055
0.1554	0.078
0.1560	0.105
0.1565	0.140
0.1575	0.230
0.1589	0.338
0.1601	0.416
0.1611	0.477
0.1623	0.542
0.1632	0.577
0.1643	0.619
0.1655	0.652
0.1672	0.696
0.1682	0.715
0.1691	0.733
0.1707	0.758
0.1725	0.776
0.1749	0.794
0.1775	0.806
0.1797	0.810
0.1830	0.810
0.1858	0.813
0.1885	0.813
0.1900	0.811
CURVE 32	
T = 298.	
1.000	0.924
1.097	0.927
1.254	0.927
1.323	0.891
1.379	0.919

TABLE 11-24. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA (VITREOUS) (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ
CURVE 32 (CONT.)	
1.425	0.931
1.597	0.934
2.027	0.934
2.071	0.926
2.108	0.896
2.148	0.834
2.171	0.754
2.191	0.721
2.214	0.738
2.214	0.812
2.256	0.887
2.300	0.912
2.369	0.912
2.409	0.895
2.492	0.800
2.575	0.700
2.609	0.652
2.637	0.108
2.637	0.024
2.678	0.000
2.730	0.003
2.805	0.032
2.805	0.364
2.832	0.501
2.861	0.599
2.888	0.703
2.912	0.749
2.957	0.782
3.029	0.827
3.093	0.849
3.201	0.871
3.350	0.871
3.416	0.858
3.494	0.798
3.562	0.696
3.636	0.603
3.693	0.499
3.746	0.435
3.800	0.417
3.914	0.417

λ	τ
CURVE 32 (CONT.)	
3.995	0.394
4.135	0.219
4.208	0.159
4.291	0.111
4.377	0.047
4.427	0.000
4.469	0.000
4.522	0.024
4.577	0.024
4.615	0.000
CURVE 33	
T = 293.	
0.82	0.951
0.88	0.962
0.89	0.965
1.23	0.955
1.32	0.964
1.75	0.964
1.95	0.967
2.02	0.965
2.09	0.960
2.17	0.960
2.27	0.964
2.36	0.964
2.44	0.954
2.49	0.936
2.54	0.917
2.57	0.899
2.59	0.871
2.62	0.836
2.65	0.750
2.66	0.722
2.66	0.692
2.68	0.643
2.70	0.706
2.74	0.776
2.79	0.852
2.79	0.884

λ	τ
CURVE 33 (CONT.)	
2.83	0.905
2.89	0.928
2.96	0.944
2.99	0.950
3.05	0.950
3.10	0.942
3.15	0.927
CURVE 34	
T = 773.	
0.83	0.936
1.06	0.936
1.13	0.927
1.19	0.920
1.30	0.925
1.35	0.930
1.49	0.93[illegible]
1.63	0.932
2.41	0.932
2.46	0.920
2.57	0.899
2.59	0.871
2.62	0.836
2.65	0.750
2.66	0.722
2.66	0.692
2.69	0.643
2.70	0.706
2.74	0.776
2.79	0.852
2.83	0.876
2.88	0.895
2.92	0.910
2.99	0.918
3.07	0.918
3.13	0.913
3.22	0.909

λ	τ
CURVE 35	
T = 973.	
0.84	0.873
0.99	0.876
1.13	0.879
1.20	0.897
1.28	0.909
1.38	0.909
1.45	0.902
1.57	0.902
1.77	0.913
2.03	0.913
2.30	0.909
2.45	0.903
2.53	0.889
2.56	0.864
2.60	0.812
2.66	0.722
2.66	0.692
2.68	0.643
2.70	0.706
2.74	0.776
2.79	0.852
2.82	0.871
2.91	0.882
2.99	0.882
3.09	0.873
3.23	0.371
CURVE 36	
T = 1173.	
0.83	0.840
0.88	0.850
0.97	0.856
1.07	0.865
1.26	0.865
1.37	0.873
1.53	0.877
1.64	0.866
1.74	0.872

λ	τ
CURVE 36 (CONT.)	
1.95	0.872
2.06	0.864
2.17	0.864
2.31	0.866
2.40	0.862
2.48	0.852
2.51	0.842
2.55	0.801
2.58	0.733
2.61	0.684
2.65	0.648
2.69	0.603
2.73	0.679
2.77	0.728
2.79	0.788
2.82	0.817
2.85	0.840
2.87	0.852
2.95	0.859
3.06	0.859
3.22	0.852
CURVE 37	
T = 293.	
2.0	0.942
2.4	0.911
2.5	0.594
2.7	0.702
3.0	0.652
3.4	0.813
3.7	0.211
3.8	0.136
4.2	0.192
4.5	0.057
4.7	0.000
41.7	0.000
42.4	0.037
43.0	0.121
44.0	0.138

λ	τ
CURVE 37 (CONT.)	
45.0	0.166
46.1	0.213
47.7	0.297
50.0	0.373
CURVE 38	
T = 293.	
3.7	<0.005
4.0	<0.005
4.5	<0.005
5.0	<0.005
5.5	<0.005
6.0	<0.005
6.5	<0.005
7.0	<0.005
7.5	<0.005
8.0	<0.005
8.5	<0.005
9.0	<0.005
9.5	<0.005
10.0	<0.005
10.5	<0.005
11.0	<0.005
11.5	<0.005
12.0	<0.005
12.5	<0.005
13.0	<0.005
13.5	<0.005
14.0	<0.005
14.5	<0.005
15.0	<0.005
15.5	<0.005
16.0	<0.005

i. Normal Spectral Transmittance (Temperature Dependence)

No experimental data sets were found for the temperature dependence of the normal spectral transmittance of vitreous silica. However, a provisional curve was arrived at for the G.E. type 106 fused quartz kind of vitreous silica for 3.8 μm by using curves 1-5 from the previous section on the wavelength dependence of the normal spectral transmittance. The values are listed in Table 11-25 and shown in Figure 11-19. The provisional values are valid for a 2.8 mm thick specimen of polished G.E. type 106 fused quartz at 298, 373, 473, 573, and 673 K.

TABLE 11-25. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (TEMPERATURE DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

T	τ
GE TYPE 106 2.8MM THICK λ = 3.8	
298.	0.600
373.	0.600
473.	0.590
573.	0.560
673.	0.530

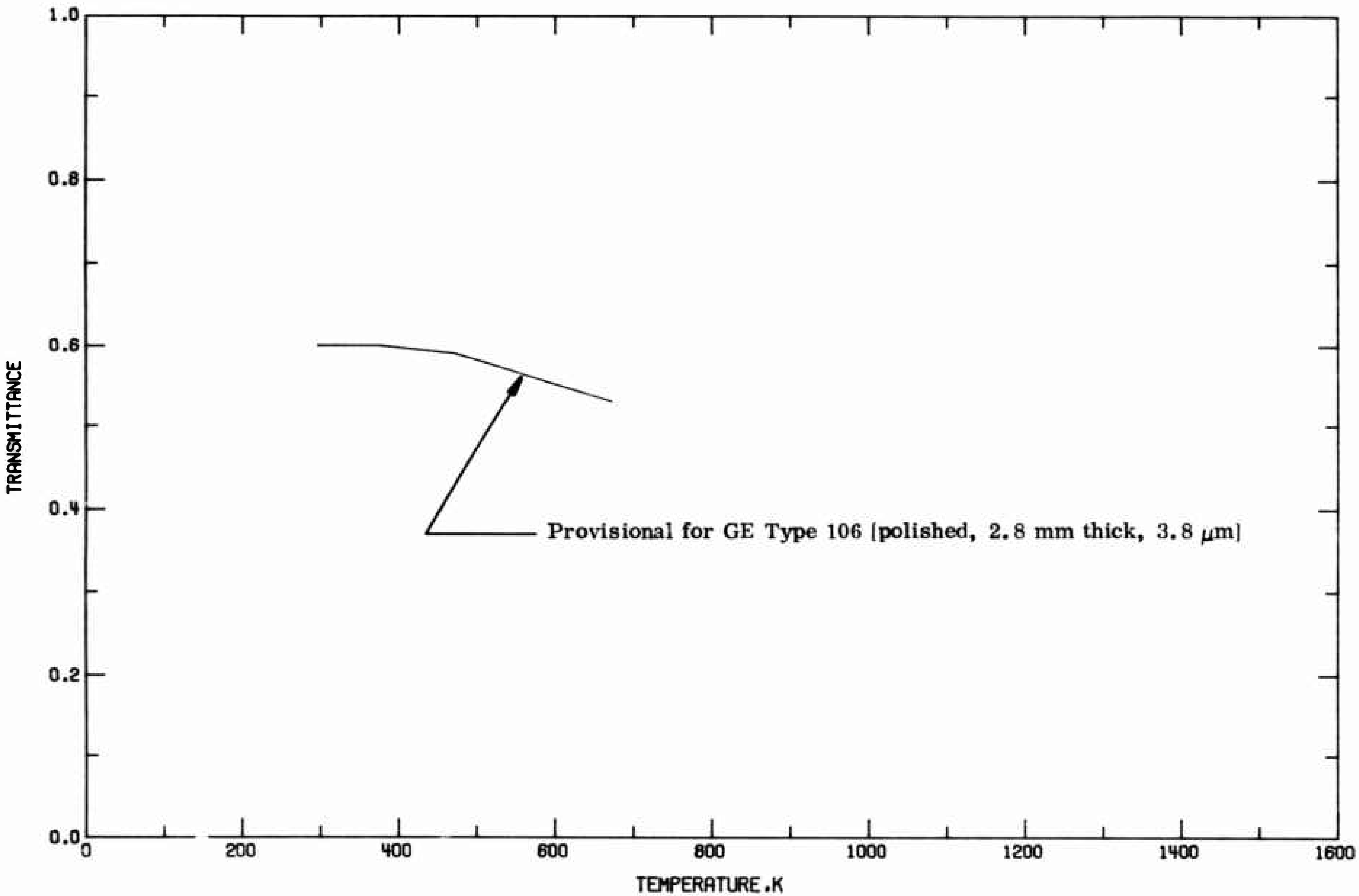


FIGURE 11-19. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF SILICA(VITREOUS) (TEMPERATURE DEPENDENCE).

4.12. Silicon

Silicon crystallizes in a face centered cubic crystal of the A4 diamond type which is very stable from 293-1573 K. The lattice parameter of high purity silicon is 5.43089 Å at 296 K [E30683] and 5.445 Å at 1573 K [A00007]. Its density is 2.42 g cm^{-3} at 293 K. At 300 K, the intrinsic resistivity of very high purity silicon is about 2.5 x 10^5 ohm-cm. The energy band gap is 1.1 eV. Silicon melts at 1687 K and boils at about 2753 K. Below 1273 K it is a brittle material, but it can be caused to undergo substantial plastic deformation at higher temperatures.

The thermal radiative properties of silicon depend on the method used in producing the crystal, especially in the 9 μm region where the presence of occluded oxygen causes a broad absorption band. In general, the bulk oxygen content is high for crystals grown by the Czochralski method and other methods where there is direct contact between the molten silicon and silica containers, and the 9 μm peak will be correspondingly higher for these crystals. Floating zone or pedestal methods have been developed in order to circumvent the problem of contamination of the crystal by the container. Oxygen is known to be present in Czochralski-grown crystals in concentrations in the range (0.5-2.0) x 10^{18} atoms cm^{-3}. Crystals grown by float zone and pedestal methods contain essentially no oxygen. Pagot [E65870] and Hu and Patrick [E66704] have discussed various methods of determining the bulk oxygen content of a crystal and have examined the effect of bulk oxygen on the magnitude of the 9 μm absorption band in crystals grown by the different methods.

The thermal radiative properties of silicon may be altered by surface oxidation as well as by bulk oxygen occluded in crystal growth. Silicon oxidizes rapidly at room temperature to form a protective layer of silica about 10 Å thick. More complete oxidation begins at 920 K but is not rapid up to about 1500 K. The oxide layer is amorphous to about 1500 K, crystalline above 1500 K, and is somewhat volatile above 1873 K. Silicon semiconductor devices are generally protected with a silica layer by oxidizing at 1400-1600 K.

Silicon is used as the starting material for silicone resins, oils, and elastomers and as an alloying element to strengthen aluminum, magnesium, copper and other metals. It has a deoxidizing effect on steel and in relatively large concentrations it confers chemical inertness on ferrous alloys. High purity silicon is used in semiconduction devices such as rectifiers and transistors, and in solar batteries. High purity silicon has also been studied for use as an infrared dome material for small air to air missiles [T10703]. For this prupose it can be used in the 1-12 μm range up to about 520 K. Above

this temperature it becomes increasingly opaque due to absorption by free carriers thermally excited to the conduction band. Extremely small amounts of impurities greatly curtail its transmittance. For dome construction, the most feasible fabrication method appears to be a form of shell casting [T48097]. The transmittance of the castings was found to be similar to grown polycrystalline material. Vapor deposited domes have improved transmission characteristics in the 9 μm region due to a lesser bulk oxygen content, but their transmission in the 1-8 μm region was found to be considerably lower than that of cast domes due to scattering by voids in the silicon about 1 μm in diameter [T48097]. In applications as infrared optical components, silicon is normally coated with other materials in order to reduce reflection losses at desired wavelengths.

The electrical and thermal radiative properties of silicon are significantly changed by additions of small amounts of impurities or dopants. Elements of the third group of the periodic table (boron, aluminum, indium, gallium) can be added to pure or intrinsic material to produce p-type silicon which conducts current by migration of electron vacancies or holes. The introduction of Group V elements (arsenic, antimony, phosphorus) produces n-type silicon in which current is carried by migration of extra electrons. The resistivity of silicon is greatly reduced by addition of these impurities, to as low a value as 10^{-4} ohm-cm. Although very pure silicon with a room temperature resistivity of the order of 10^5 ohm-cm and which becomes an intrinsic conductor at as low a temperature as 313 K has been produced, the term "high resistivity silicon" in the following discussion has generally been applied to silicon with a room temperature resistivity of 5 ohm-cm or greater.

The absorption mechanisms responsible for the main thermal radiative characteristics of silicon can be classified into four different types [T48288]: i) intrinsic absorption associated with excitation of electrons from the valence band to the conduction band across the energy gap; ii) absorption associated with impurities or defects in the lattice; iii) absorption due to the presence of free carriers; and iv) absorption due to lattice vibrations. Intrinsic absorption accounts for the sharp increase of the emittance and sharp decrease of the transmittance of silicon at around 1 μm. At longer wavelengths, the radiation has insufficient energy to excite an electron across the energy gap, and the absorption and emittance are low with correspondingly high transmittance. In the 6-15 μm wavelength range, absorption bands associated with lattice vibrations are evident. At room temperature, absorption due to free carriers is not great for silicon of ordinary purity, but as the temperature is raised, the silicon becomes intrinsic as electrons are thermally excited to the conduction band. The free carrier absorption increases rapidly with temperature and finally becomes the dominant absorption mechanism.

It should be noted that the following sections concentrate on pure silicon with relatively low dopant levels. The experimental data for doped silicon samples shown in the following tables and figures by no means represent an exhaustive coverage of the available data for doped samples in the 1-15 μm range.

a. Normal Spectral Emittance (Wavelength Dependence)

Fifty-one experimental data sets for the wavelength dependence (1-14 μm) of the normal spectral emittance of silicon covering the temperature range 77-1075 K are shown in Table 12-3 and Figures 12-2 and 12-3. Of the 51 data sets, 30 sets are for specimens with relatively low dopant levels and high resistivities. Data for relatively pure specimens are shown in Figure 12-2 and for doped, low resistivity specimens in Figure 12-3.

Silicon is a partially transparent material to which the McMahon [T20468] relations (Eq. 2.6-10 to 2.6-12) apply. As the relations indicate, the normal spectral emittance of silicon depends on the thickness of the specimen, unless the specimen is thick enough or at high enough temperatures to be opaque. In this case, the normal spectral emittance is given by Eq. 2.6-1, where $\rho(\lambda, T)$ is the single surface reflectance given by Eq. 2.4-11 and Eq. 2.6-6. For high purity silicon in the 2-15 μm wavelength range, the index of absorption is small compared to the refractive index and can be neglected in Eq. 2.4-11. Both measurements of the refractive index and of the reflectance of opaque specimens indicate that the single surface reflectance of polished, high purity silicon at room temperature has a nearly constant value of 0.30 over the entire 2-15 μm wavelength range. The room temperature emittance of a polished, opaque specimen of relatively pure silicon can therefore be given as 0.70 in the 2-15 μm region. The uncertainty of this value should not be greater than ± 5%.

The normal spectral emittance of transparent specimens of relatively pure silicon has been extensively investigated by Stierwalt [T16961, T28823] (curves 25-38) Stierwalt and Potter [T32537] (curves 4-9) and Sato [T41640] (curves 39-45). Stierwalt, investigating primarily the emittance due to lattice vibrations, observed emission bands at 5.85, 7.0, 7.8, 9.0, 10.4, 11.3, 12.25, 12.8, and 13.6 μm. Both n-type and p-type silicon show the same emission bands. The 9 μm band is due to bulk oxygen impurities. Stierwalt found that the 9.0 and 11.3 μm bands shift to longer wavelengths as the temperature is increased, the shift being about 0.1 μm when the temperature was raised from 333 to 433 K. Sato and other investigators have observed similar lattice emission bands. Sato found, from measurements on a 15 ohm-cm, n-type specimen, that the lattice emission

increases with temperature from 340 K, reaches a maximum at 493 K, and then decreases with further increasing temperature.

The recommended values for 330 K shown in Table 12-1 and Figure 12-1 are based on Stierwalt's data (curve 25) for a 2.03 mm thick, n-type, 30-60 ohm-cm silicon single crystal. In the 1-3 μm region, the recommended values were generated in a manner consistent with transmittance and reflectance data and with the general trend of Sato's data for higher temperatures. Stierwalt's data were not followed closely in the 9 μm region; rather, an average peak height was chosen for the emission band due to occluded oxygen, because the height of the peak is known to vary greatly according to the method used to grow the crystal. Stierwalt also performed measurements (curves 4-9, 31-34) on two 1.68 mm thick, p-type samples of similar resistivity. In the 7-14 μm region, these samples show a lower emittance than the slightly thicker n-type sample. Thus, the 330 K recommended values may be considered to apply to a 2 mm thick, n-type silicon single crystal of relatively high purity and resistivity. They do not apply to highly doped specimens.

The uncertainties of the values recommended for 330 K vary according to the wavelength. Due to the rapid increase in emittance near the absorption edge (1-1.5 μm), the values in this region must be considered typical only; their uncertainty may be as great as 50%. In the 2-5 μm region, the emittance is very small, varying from about 0.01 to 0.03 for the n-type and p-type specimens with thicknesses of about 2 mm. In the 6-14 μm range, the uncertainty should not be greater than $\pm 15\%$, with the exception of the 9 μm emission peak, where experimental measurements for crystals grown by different methods may differ from the tabulated values by as much as 80-90%.

The recommended values for 1075 K shown in Table 12-1 and Figure 12-1 are based on Sato's data (curve 45) for a 1.77 mm thick, n-type, 15 ohm-cm single crystal. At this high temperature, silicon is opaque in the 2-15 μm range, and absorption due to free carriers dominates the lattice absorption. Sato's data shows that the normal spectral emittance is within $\pm 5\%$ of 0.710 over the entire 2-15 μm range. This value for the emittance, along with Eq. 2.6-1 for opaque materials, gives a single surface reflectance of 0.290 at 1075 K, which compares favorably with the room temperature value of 0.30. Because of the high temperature opacity of silicon, the 1075 recommended values are applicable to relatively pure, high resistivity, single crystal silicon of any thickness. The uncertainty of the recommended values should not exceed $\pm 8\%$.

No recommendations have been made for highly doped p-type or n-type specimens. The normal spectral emittance of silicon specimens which are sufficiently doped to be

opaque can be calculated by use of the free carrier absorption theory. Using this theory, Sato [T41640] performed calculations (curves 50, 51) at 543 and 893 K which show good agreement with experimental data (curves 46, 49) for an n-type specimen. Calculations performed by Liebert [T47262], showed agreement with experimental data to within 14%, for both n-type and p-type specimens for temperatures from 300 to 1075 K and wavelengths from 3.5 to 14.8 μm. The Hagen-Rubens theory is inadequate for doped silicon in the 1-15 μm region [T47262].

TABLE 12-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF HIGH RESISTIVITY SILICON (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε	λ	ε
SINGLE CRYSTAL 2.0 MM THICK T = 330		SINGLE CRYSTAL 2.0 MM THICK T = 330 (CONT.)		SINGLE CRYSTAL 2.0 MM THICK T = 330 (CONT.)		SINGLE CRYSTAL OPAQUE T = 1375	
1.00	0.665	8.20	0.104	12.10	0.390	1.00	0.664
1.10	0.575	8.30	0.114	12.20	0.410	1.50	0.687
1.20	0.220B†	8.40	0.146	12.30	0.397	2.00	0.700
1.30	0.024B	8.50	0.179B†	12.40	0.389	2.50	0.712
1.40	0.017B	8.60	0.220B	12.50	0.391	3.00	0.714
1.50	0.014B	8.70	0.280B	12.60	0.403	3.50	0.714
1.60	0.013B	8.80	0.366B	12.70	0.417	4.00	0.714
1.70	0.012A	8.90	0.435B	12.80	0.427	4.50	0.715
1.80	0.011A	9.00	0.472B	12.90	0.433	5.00	0.716
1.90	0.011A	9.10	0.470B	13.00	0.439	6.00	0.716
2.00	0.010A	9.20	0.420B	13.10	0.443	7.00	0.716
2.20	0.010A	9.30	0.320B	13.20	0.451	8.00	0.716
2.40	0.009A	9.40	0.188B	13.30	0.460	9.00	0.716
2.60	0.009A	9.50	0.165	13.40	0.470	10.00	0.716
2.80	0.009A	9.60	0.158	13.50	0.482	10.60	0.716
3.00	0.009A	9.70	0.169	13.60	0.478	11.00	0.716
3.80	0.009A	9.80	0.190	13.70	0.446	12.00	0.716
4.00	0.009A	9.90	0.210	13.80	0.414	13.00	0.713
5.00	0.010A	10.00	0.234	13.90	0.367	14.00	0.712
5.50	0.013A	10.10	0.260	14.00	0.310	15.00	0.710
5.85	0.024	10.20	0.284				
6.00	0.022	10.30	0.305				
6.20	0.021	10.40	0.309				
6.40	0.023	10.50	0.306				
6.60	0.038	10.60	0.308				
6.80	0.083	10.70	0.329				
6.90	0.105	10.80	0.350				
7.00	0.112	10.90	0.373				
7.10	0.104	11.00	0.394				
7.20	0.100	11.10	0.410				
7.30	0.100	11.20	0.417				
7.40	0.104	11.30	0.417				
7.50	0.115	11.40	0.409				
7.60	0.125	11.50	0.392				
7.70	0.130	11.60	0.375				
7.80	0.122	11.70	0.358				
7.90	0.113	11.80	0.350				
8.00	0.103	11.90	0.350				
8.10	0.100	12.00	0.368				

† VALUE FOLLOWED BY AN "A" IS PROVISIONAL AND BY A "B" IS TYPICAL.

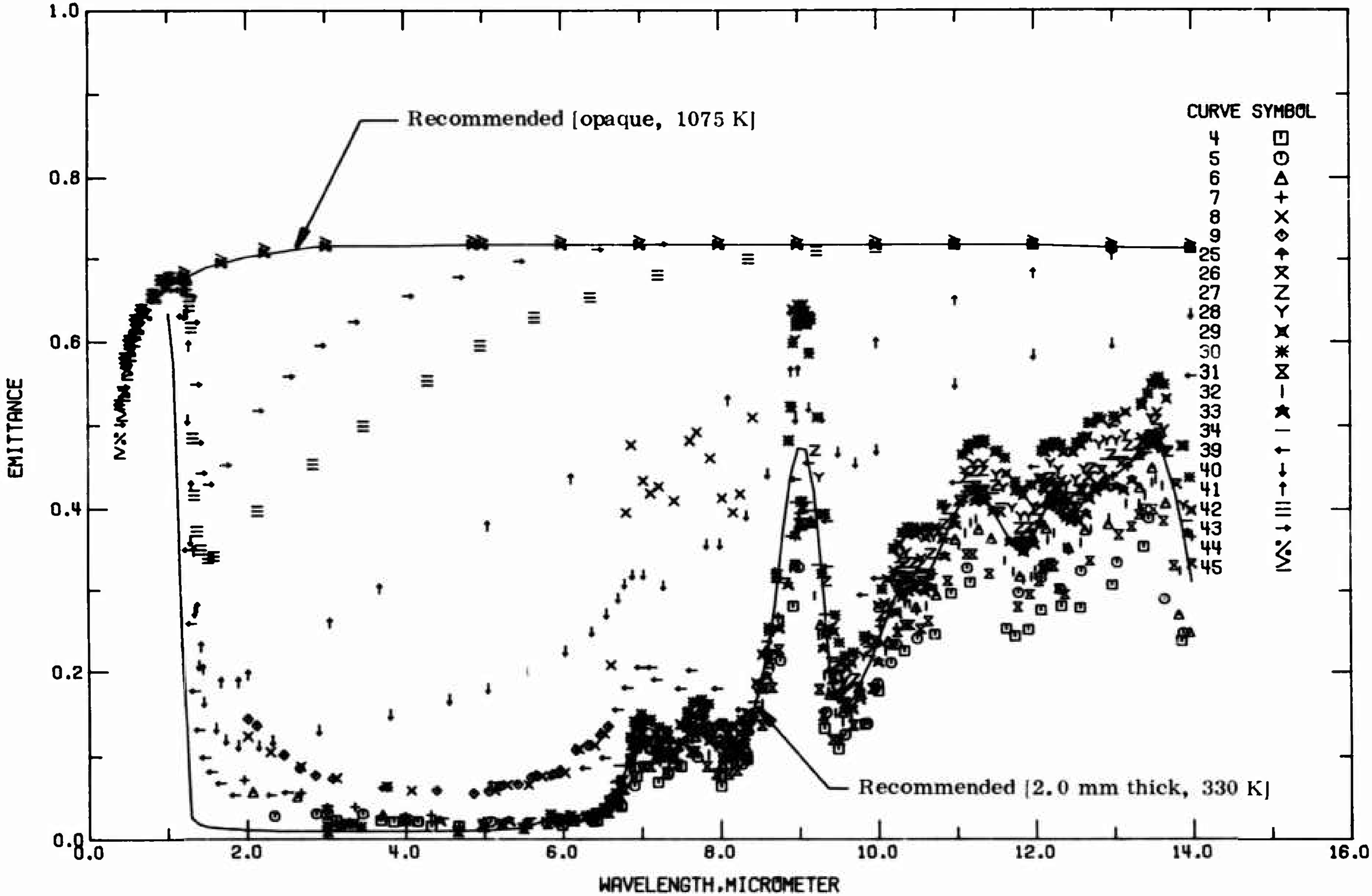


FIGURE 12-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF HIGH-RESISTIVITY SILICON (WAVELENGTH DEPENDENCE)

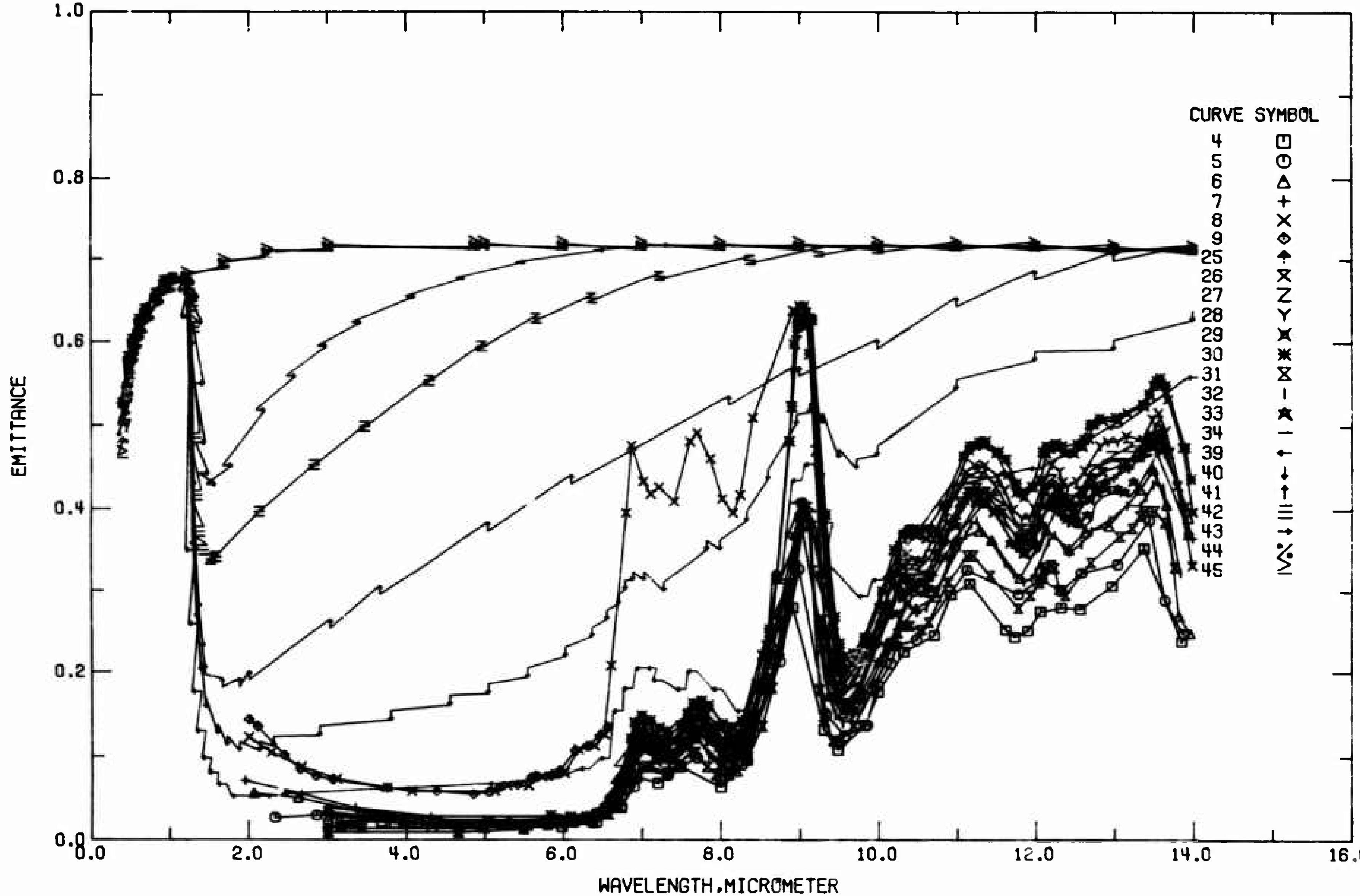


FIGURE 12-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF HIGH-RESISTIVITY SILICON (WAVELENGTH DEPENDENCE).

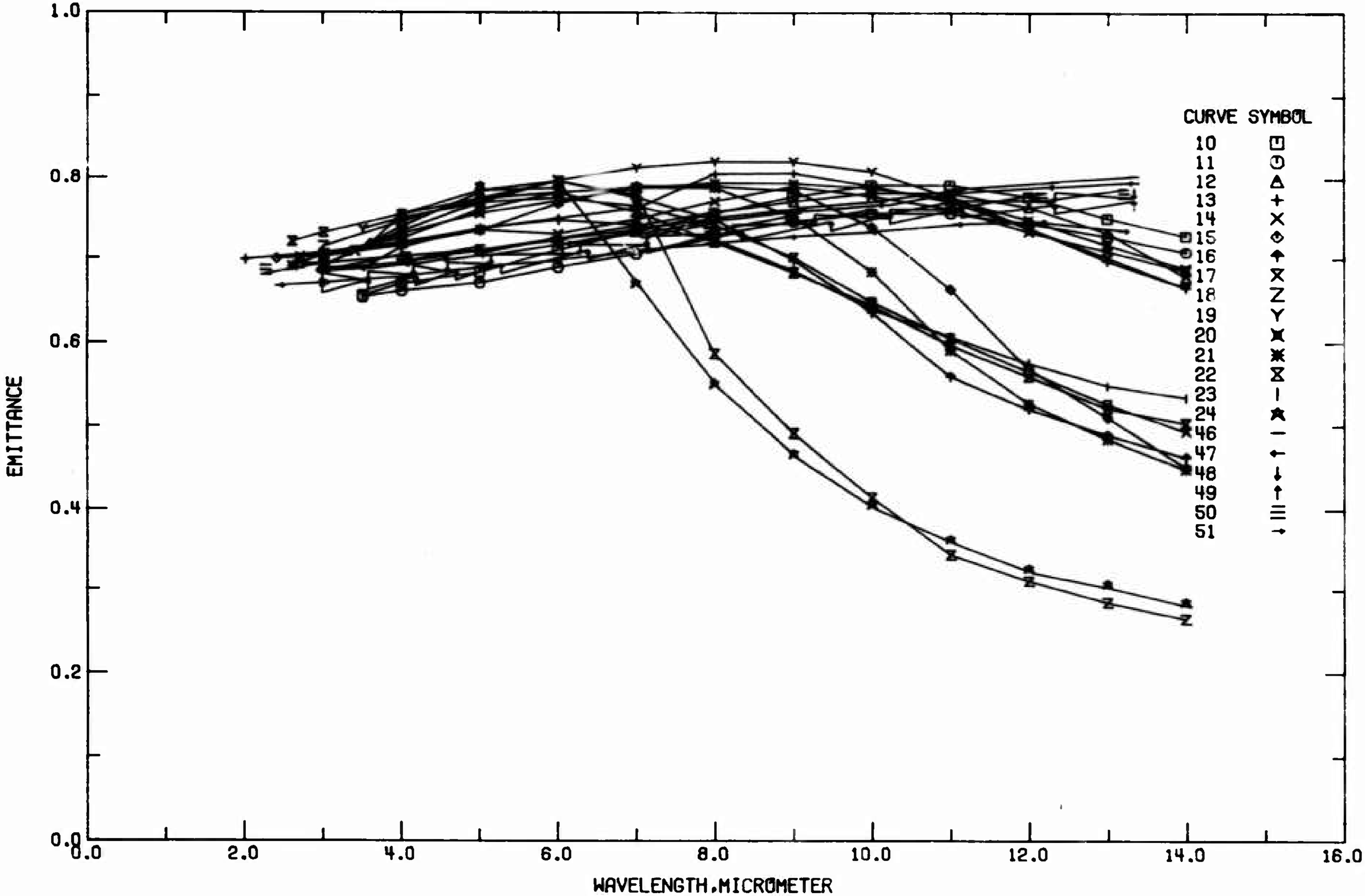


FIGURE 12-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF LOW-RESISTIVITY, DOPED SILICON (WAVELENGTH DEPENDENCE).

TABLE 12-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF SILICON (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T39952	Stierwalt, D.L.	1966	16-42	77		Single crystal; n-type; 2 mm thick; 10^{-4} torr pressure; smoothed values extracted from figure.
2	T39952	Stierwalt, D.L.	1966	16-42	203		Similar to the above specimen.
3	T39952	Stierwalt, D.L.	1966	16-42	373		Similar to the above specimen.
4	T32537	Stierwalt, D.L. and Potter, R.F.	1962	2-24	323		Single crystal; p-type; thickness 1.68 mm; cut to size with ultrasonic tool; optical surfaces prepared using standard lapping and polishing techniques; not etched; resistivity of 30 ohm-cm; data presented in figure.
5	T32537	Stierwalt, D.L. and Potter, R.F.	1962	2-24	373		The above specimen measured at 373 K.
6	T32537	Stierwalt, D.L. and Potter, R.F.	1962	2-24	423		The above specimen measured at 423 K.
7	T32537	Stierwalt, D.L. and Potter, R.F.	1962	2-24	473		The above specimen measured at 473 K.
8	T32537	Stierwalt, D.L. and Potter, R.F.	1962	2-9	473		Single crystal; p-type; thickness 13.4 mm; cut to size with ultrasonic tool; optical surfaces prepared using standard lapping and polishing techniques; not etched; resistivity of 2000 ohm-cm; data presented in figure.
9	T32537	Stierwalt, D.L. and Potter, R.F.	1962	2-7	473		The above specimen measured with increased gain.
10	T47262	Liebert, C.H.	1967	3.5-14.8	882		n-type single crystal; doped with arsenic; carrier concentration 2.2×10^{19} electrons cm^{-3} (accurate to ± 1%); opaque disk 23 mm diameter and 1.6 mm thick cut from doped ingots made by Allegheny Electron Chemicals Co; optically polished and etched; width of ridges produced by polishing about 0.5 μm; measured in air; hohlraum and Perkin Elmer Model 13 spectrophotometer used; data presented in figure; oxidation effects considered to be negligible; resistivity about 0.00644 ohm-cm at 882 K; reported error ±4-7%.
11	T47262	Liebert, C.H.	1967	3.5-14.8	1074		The above specimen measured at 1074 K; resistivity about 0.00793 ohm cm at 1074 K.
12	T47262	Liebert, C.H.	1967	2.5-35	300		The above specimen; normal spectral emissivity calculated from measurements of near normal (6°) specular reflectivity using hohlraumand Perkin Elmer Model 521 spectrophotometer, with aluminum mirror as standard; data reported in figure; resistivity about 0.00329 at 300 K.
13	T47262	Liebert, C.H.	1967	3.5-14.8	882		n-type single crystal doped with arsenic; carrier concentration 3.7×10^{19} electrons cm^{-3} (accurate to ± 1%); opaque disk 23 mm in diameter and 1.6 mm thick cut from ingots made by Allegheny Electron Chemicals Co; optically polished and etched; width of ridges produced by polishing 0.5 μm; measured in air using hohlraum and Perkin Elmer Model 13 spectrophotometer; oxidation effects considered to be negligible; data presented in figure; resistivity about 0.00429 ohm cm at 882 K; reported error ±4-7%.
14	T47262	Liebert, C.H.	1967	3.5-14.8	1074		The above specimen measured at 1074 K; resistivity about 0.00524 ohm-cm at 1074 K.
15	T47262	Liebert, C.H.	1967	2.5-35	300		The above specimen; normal spectral emissivity calculated from measurements of near normal (6°) specular reflectivity using hohlraum and Perkin-Elmer Model 521 spectrophotometer with aluminum mirror as standard; data reported in figure; resistivity about 0.00206 ohm-cm at 300 K.

TABLE 12-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF SILICON (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
16	T47262	Liebert, C.H.	1967	3.5-14.8	882		n-type single crystal doped with arsenic; carrier concentration 8.5×10^{19} electrons cm^{-3} (accurate to $\pm 1\%$); opaque disk 23 mm diameter and 1.6 mm thick cut from ingot made by Allegheny Electron Chemicals Co; optically polished and etched; width of ridges produced by produced by polishing about 0.5 μm; measured in air using hohlraum and Perkin Elmer Model 13 spectrophotometer; oxidation effects considered to be negligible; data presented in figure; electrical resistivity about 0.00238 ohm-cm at 882 K; reported error $\pm$4-7%.
17	T47262	Liebert, C.H.	1967	3.5-14.8	1074		The above specimen measured at 1074 K; resistivity about 0.00292 ohm-cm at 1074 K.
18	T47262	Liebert, C.H.	1967	2.5-35	300		The above specimen; normal spectral emissivity calculated from measurements of near normal (6°) specular reflectivity using hohlraum and Perkin Elmer Model 521 spectrophotometer with aluminum mirror as standard; data reported in figure; electrical resistivity about 0.00115 ohm-cm at 300 K.
19	T47262	Liebert, C.H.	1967	3.5-14.8	882		p-type single crystal doped with boron; carrier concentration 6.2×10^{19} holes-cm^{-3} (accurate to $\pm 1\%$); opaque disk 23 mm in diameter and 1.6 mm thick cut from ingot made by Allegheny Electron Chemicals Co; optically polished and etched; width of ridges produced by polishing about 0.5 μm; measured in air using hohlraum and Perkin Elmer Model 13 spectrophotometer; oxidation effects considered to be negligible; data presented in figure; electrical resistivity about 0.00479 ohm cm at 882 K; reported error $\pm$4-7%.
20	T47262	Liebert, C.H.	1967	3.5-14.8	1074		The above specimen measured at 1074 K; electrical resistivity about 0.00588 ohm cm at 1074 K.
21	T47262	Liebert, C.H.	1967	2.5-35	300		The above specimen; normal spectral emissivity calculated from measurements of near normal (6°) specular reflectivity using hohlraum and Perkin Elmer Model 521 spectrophotometer with aluminum mirror as standard; data presented in figure; electrical resistivity about 0.00218 ohm cm at 300 K.
22	T47262	Liebert, C.H.	1967	3.5-14.8	882		p-type single crystal doped with boron; carrier concentration 1.4×10^{20} holes-cm^{-3} (accurate to $\pm 1\%$); opaque disk 23 mm in diameter and 1.6 mm thick cut from ingot made by Allegheny Electron Chemicals Co; optically polished and etched; width of ridges produced by polishing about 0.5 μm; measured in air using hohlraum and Perkin Elmer Model 13 spectrophotometer; oxidation effects considered to be negligible; data presented in figure; electrical resistivity about 0.00281 ohm-cm 882 K; reported error $\pm$4-7%.
23	T47262	Liebert, C.H.	1967	3.5-14.8	1074		The above specimen measured at 1074 K; electrical resistivity about 0.00348 ohm-cm at 1074 K.
24	T47262	Liebert, C.H.	1967	2.5-35	300		The above specimen; normal spectral emissivity calculated from measurements of near normal (6°) specular reflectivity using hohlraum and Perkin Elmer Model 521 spectrophotometer with aluminum mirror as standard; data presented in figure; electrical resistivity about 0.00124 ohm-cm at 300 K.
25	T16961	Stierwalt, D.L.	1961	3-15	333		n-type, single crystal; 2.03 mm thick; ground and polished on top and botton surfaces; measured in vacuum using modified Beckman IR-3 spectrophotometer; electrical resistivity 30-60 ohm cm; data presented in figure.
26	T16961	Stierwalt, D.L.	1961	3-15	353		The above specimen measured at 353 K.
27	T16961	Stierwalt, D.L.	1961	3-15	373		The above specimen measured at 373 K.
28	T16961	Stierwalt, D.L.	1961	3-15	393		The above specimen measured at 393 K.

TABLE 12-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF SILICON (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
29	T16961	Stierwalt, D.L.	1961	3-15	413		The above specimen measured at 413 K.
30	T16961	Stierwalt, D.L.	1961	3-15	433		The above specimen measured at 433 K.
31	T16961	Stierwalt, D.L.	1961	3-15	313		p-type, single crystal; 1.68 mm thick; ground and polished on top and bottom surfaces; measured in vacuum using modified Beckman IR-3 spectrophotometer; data presented in figure.
32	T16961	Stierwalt, D.L.	1961	3-15	353		The above specimen measured at 353 K.
33	T16961	Stierwalt, D.L.	1961	3-15	393		The above specimen measured at 393 K.
34	T16961	Stierwalt, D.L.	1961	3-15	433		The above specimen measured at 433 K.
35	T28823	Stierwalt, D.	1960	3-15	313		1.65 mm thick sample.
36	T28823	Stierwalt, D.	1960	3-15	353		The above specimen.
37	T28823	Stierwalt, D.	1960	3-15	393		The above specimen.
38	T28823	Stierwalt, D.	1960	3-15	433		The above specimen.
39	T41640	Sato, T.	1967	0.4-15	543		n-type, phosphorus doped, single crystal disk with 23 mm diameter and 1.77 mm thickness; resistivity 15 ohm-cm; ground and polished plane parallel using metallographic and then optical techniques; two measurement methods used; direct method compared specimen to V-shaped graphite cavity using Japan Spectroscopic IR-S spectrophotometer with NaCl prism in 2.5-15 μm range and a double pass spectrophotometer with LiF prism below 2.5 μ; indirect method obtained emissivity from measurements of reflectance and transmittance; measured under 10^{-4} mm Hg to preclude oxidation; due to difficulties in reading scale of figure, values above 10 μm are uncertain.
40	T41640	Sato, T.	1967	0.4-15	623		The above specimen measured at 623 K.
41	T41640	Sato, T.	1967	0.4-15	693		The above specimen measured at 693 K.
42	T41640	Sato, T.	1967	0.4-15	743		The above specimen measured at 743 K.
43	T41640	Sato, T.	1967	0.4-15	793		The above specimen measured at 793 K.
44	T41640	Sato, T.	1967	0.4-15	873		The above specimen measured at 873 K.
45	T41640	Sato, T.	1967	0.4-15	1073		The above specimen measured at 1073 K.
46	T41640	Sato, T.	1967	2-15	543		n-type, phosphorous doped, single crystal disk with 23 mm diameter and 0.2 mm thickness; resistivity 0.007 ohm-cm at 300 K; polished and measured in manner similar to the above specimen; practically opaque even at low temperatures; due to difficulties in reading scale of figure, values above 10 μm are uncertain.
47	T41640	Sato, T.	1967	2-15	693		The above specimen measured at 693 K.
48	T41640	Sato, T.	1967	2-15	793		The above specimen measured at 793 K.
49	T41640	Sato, T.	1967	2-15	893		The above specimen measured at 893 K.
50	T41640	Sato, T.	1967	2-15	543		Calculation of the emittance of the above specimen at 543 K.
51	T41640	Sato, T.	1967	2-15	893		Calculation of the emittance of the above specimen at 893 K.

TABLE 12-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE 1		CURVE 2(CONT.)		CURVE 3(CONT.)		CURVE 4(CONT.)		CURVE 5(CONT.)		CURVE 6	
T = 77.										T = 423.	
		17.49	0.285	30.00	0.097	12.99	0.306	9.34	0.151		
16.00	0.330	17.80	0.291	32.00	0.081	13.39	0.353	9.58	0.125	2.06	0.057
16.32	0.466	18.33	0.265	34.00	0.079	13.87	0.235	9.86	0.138	2.62	0.051
16.50	0.475	19.03	0.217	36.00	0.082	14.10	0.204	10.00	0.185	3.70	0.029
16.63	0.456	19.48	0.227	38.00	0.083	14.34	0.166	10.17	0.210	6.30	0.029
16.79	0.344	20.07	0.205	40.00	0.079	15.27	0.196	10.24	0.232	6.70	0.053
16.98	0.253	20.77	0.159	41.48	0.079	15.56	0.220	10.50	0.239	6.93	0.118
17.23	0.220	21.44	0.128			15.82	0.304	11.14	0.327	7.17	0.098
17.52	0.230	22.00	0.100	CURVE 4		16.29	0.591	11.79	0.296	7.41	0.098
17.87	0.236	24.00	0.079	T = 323.		16.49	0.564	12.08	0.315	7.68	0.123
18.20	0.224	26.00	0.073			16.92	0.391	12.33	0.300	8.02	0.091
18.92	0.176	28.00	0.066	3.12	0.022	17.16	0.366	12.59	0.323	8.32	0.110
19.39	0.187	30.00	0.063	3.69	0.022	17.36	0.349	13.05	0.334	8.62	0.210
19.87	0.166	32.00	0.057	3.85	0.020	17.65	0.354	13.45	0.387	9.04	0.379
20.44	0.122	34.00	0.051	4.15	0.021	18.57	0.306	13.65	0.288	9.27	0.257
20.86	0.101	36.00	0.048	4.33	0.015	19.01	0.291	13.89	0.246	9.38	0.172
21.33	0.086	38.00	0.046	4.68	0.015	19.35	0.296	14.22	0.190	9.55	0.152
21.77	0.072	40.00	0.041	5.99	0.016	19.52	0.296	14.48	0.200	9.78	0.173
22.00	0.065	41.91	0.041	6.43	0.022	20.00	0.259	14.74	0.200	10.13	0.236
24.00	0.045			6.74	0.039	21.72	0.170	15.13	0.216	10.49	0.278
26.00	0.039	CURVE 3		6.93	0.076	22.70	0.137	15.45	0.231	10.75	0.293
28.00	0.032	T = 373.		7.21	0.069			15.63	0.251	10.99	0.362
30.00	0.027			7.50	0.088	CURVE 5		15.83	0.309	11.29	0.374
32.00	0.027	16.00	0.362	8.01	0.064	T = 373.		16.18	0.637	11.45	0.363
34.00	0.025	16.37	0.616	8.34	0.096			16.32	0.652	11.81	0.317
36.00	0.026	16.63	0.587	8.93	0.279	2.33	0.027	16.68	0.555	12.15	0.375
38.00	0.026	17.25	0.409	9.32	0.132	2.86	0.030	16.92	0.424	12.43	0.352
40.00	0.026	17.48	0.399	9.50	0.109	3.45	0.030	17.37	0.381	12.64	0.373
41.66	0.026	18.03	0.399	9.84	0.137	4.15	0.021	17.63	0.396	12.94	0.380
		18.27	0.389	10.01	0.176	5.07	0.021	18.15	0.373	13.34	0.424
CURVE 2		18.65	0.369	10.34	0.224	6.37	0.021	18.56	0.339	13.50	0.448
T = 203.		18.93	0.336	10.73	0.244	6.74	0.041	19.09	0.326	13.67	0.406
		19.23	0.324	10.94	0.295	6.90	0.065	19.41	0.343	13.83	0.269
16.00	0.357	19.92	0.317	11.18	0.309	6.96	0.087	20.14	0.291	13.97	0.247
16.19	0.550	20.67	0.268	11.64	0.251	7.33	0.079	20.61	0.264	14.27	0.233
16.42	0.561	21.40	0.230	11.75	0.242	7.70	0.099	21.60	0.200	14.46	0.245
16.60	0.547	22.00	0.207	11.92	0.250	7.99	0.076	22.61	0.152	14.69	0.245
16.90	0.393	24.00	0.160	12.09	0.274	8.27	0.091	23.21	0.138	14.99	0.268
17.05	0.335	26.00	0.125	12.34	0.279	8.76	0.213	24.00	0.125	15.52	0.294
17.22	0.301	28.00	0.096	12.58	0.277	9.00	0.328			15.75	0.337

TABLE 12-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε
CURVE 6 (CONT.)	
16.04	0.605
16.34	0.721
16.95	0.467
17.29	0.451
17.51	0.469
17.73	0.469
17.93	0.452
17.93	0.431
18.43	0.424
18.94	0.394
19.41	0.412
20.00	0.358
20.54	0.329
21.11	0.277
21.42	0.260
21.88	0.216
23.08	0.178
24.00	0.161
CURVE 7	
T = 473.	
1.95	0.072
2.67	0.056
3.35	0.039
4.31	0.029
6.05	0.029
6.51	0.034
6.68	0.071
6.96	0.132
7.25	0.116
7.46	0.116
7.58	0.138
7.74	0.147
8.09	0.116
8.33	0.125
8.73	0.266
9.81	0.394
9.16	0.385
9.54	0.188
CURVE 7 (CONT.)	
9.89	0.243
10.03	0.255
10.27	0.298
10.71	0.320
11.29	0.412
11.84	0.363
12.07	0.384
12.22	0.416
12.41	0.409
12.63	0.428
13.00	0.438
13.46	0.488
14.00	0.365
14.31	0.276
14.78	0.292
15.53	0.318
15.84	0.375
16.27	0.731
16.49	0.707
17.30	0.484
17.65	0.510
18.53	0.454
19.23	0.430
19.47	0.440
21.59	0.292
22.67	0.251
23.41	0.217
24.00	0.202
CURVE 8	
T = 473.	
2.00	0.123
2.28	0.105
2.67	0.088
3.12	0.074
3.76	0.064
4.07	0.059
5.13	0.059
5.29	0.066
CURVE 8 (CONT.)	
5.56	0.066
5.73	0.077
6.02	0.081
6.20	0.109
6.40	0.113
6.52	0.127
6.61	0.208
6.81	0.395
6.88	0.476
7.03	0.433
7.12	0.418
7.23	0.426
7.42	0.409
7.62	0.481
7.71	0.491
7.88	0.460
8.03	0.412
8.17	0.395
8.26	0.417
8.42	0.509
8.93	0.637
CURVE 9	
T = 473.	
2.00	0.1436
2.11	0.1357
2.45	0.1015
2.65	0.0855
2.85	0.0771
3.07	0.0730
3.76	0.0631
4.39	0.0591
4.86	0.0556
5.05	0.0580
5.19	0.0643
5.42	0.0669
5.59	0.0752
5.65	0.0775
5.86	0.0791
CURVE 9 (CONT.)	
5.96	0.0836
6.16	0.1076
6.31	0.1127
6.47	0.1250
6.57	0.1348
CURVE 10	
T = 892.	
3.5	0.654
4.0	0.668
5.0	0.682
6.0	0.709
7.0	0.732
8.0	0.755
9.0	0.776
10.0	0.791
11.0	0.791
12.0	0.776
13.0	0.749
14.0	0.727
15.0	0.694
CURVE 11	
T = 1074.	
3.5	0.652
4.0	0.659
5.0	0.669
6.0	0.688
7.0	0.704
8.0	0.728
9.0	0.745
10.0	0.755
11.0	0.755
12.0	0.743
13.0	0.727
14.0	0.707
14.7	0.684
CURVE 12	
T = 300.	
2.7	0.692
3.0	0.692
4.0	0.701
5.0	0.708
6.0	0.723
7.0	0.739
8.0	0.756
9.0	0.770
10.0	0.781
11.0	0.781
12.0	0.763
13.0	0.731
14.0	0.677
15.0	0.613
16.0	0.552
18.0	0.459
20.0	0.400
22.0	0.375
24.0	0.354
26.0	0.338
28.0	0.322
30.0	0.311
32.0	0.300
34.0	0.294
35.0	0.294
CURVE 13	
T = 882.	
2.0	0.697
3.0	0.705
4.0	0.718
5.0	0.735
6.0	0.748
7.0	0.761
8.0	0.805
9.0	0.806
10.0	0.796
11.0	0.770
CURVE 13 (CONT.)	
12.0	0.737
13.0	0.696
14.0	0.664
15.0	0.631
CURVE 14	
T = 1074.	
2.7	0.700
3.0	0.704
4.0	0.716
5.0	0.734
6.0	0.729
7.0	0.747
8.0	0.770
9.0	0.789
10.0	0.777
11.0	0.761
12.0	0.732
13.0	0.708
14.0	0.684
14.8	0.661
CURVE 15	
T = 300.	
2.4	0.698
3.0	0.701
4.0	0.714
5.0	0.733
6.0	0.767
7.0	0.789
8.0	0.789
9.0	0.784
10.0	0.738
11.0	0.662
12.0	0.568
13.0	0.510
14.0	0.451
15.0	0.405

TABLE 12-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 15(CONT.)	
16.0	0.368
18.0	0.329
20.0	0.304
22.0	0.290
24.0	0.278
26.0	0.269
28.0	0.260
30.0	0.254
32.0	0.244
34.0	0.238
34.8	0.238
CURVE 16 T = 882.	
3.6	0.716
4.0	0.753
5.0	0.783
6.0	0.793
7.0	0.775
8.0	0.747
9.0	0.697
10.0	0.635
11.0	0.559
12.0	0.529
13.0	0.489
14.0	0.463
14.7	0.447
CURVE 17 T = 1074.	
3.4	0.707
4.0	0.732
5.0	0.758
6.0	0.774
7.0	0.764
8.0	0.740
9.0	0.700
10.0	0.647

λ	ε
CURVE 17(CONT.)	
11.0	0.605
12.0	0.565
13.0	0.526
14.0	0.493
14.7	0.493
CURVE 18 T = 300.	
3.0	0.713
4.0	0.744
5.0	0.773
6.0	0.795
7.0	0.778
8.0	0.586
9.0	0.491
10.0	0.415
11.0	0.344
12.0	0.311
13.0	0.284
14.0	0.264
15.0	0.253
16.0	0.241
18.0	0.225
20.0	0.214
22.0	0.203
24.0	0.199
26.0	0.195
28.0	0.195
30.0	0.194
32.0	0.194
34.0	0.194
35.0	0.194
CURVE 19 T = 882.	
3.5	0.735
4.0	0.748
5.0	0.768

λ	ε
CURVE 19(CONT.)	
6.0	0.796
7.0	0.812
8.0	0.820
9.0	0.820
10.0	0.808
11.0	0.776
12.0	0.737
13.0	0.700
14.0	0.664
15.0	0.623
CURVE 20 T = 1074.	
3.0	0.690
4.0	0.729
5.0	0.754
6.0	0.770
7.0	0.786
8.0	0.793
9.0	0.793
10.0	0.787
11.0	0.774
12.0	0.747
13.0	0.716
14.0	0.687
15.0	0.649
CURVE 21 T = 300.	
2.6	0.689
3.0	0.703
4.0	0.723
5.0	0.759
6.0	0.781
7.0	0.787
8.0	0.787
9.0	0.751
10.0	0.683

λ	ε
CURVE 21(CONT.)	
11.0	0.591
12.0	0.527
13.0	0.484
14.0	0.449
15.0	0.414
16.0	0.393
18.0	0.356
20.0	0.324
22.0	0.303
24.0	0.278
26.0	0.264
28.0	0.249
30.0	0.238
32.0	0.229
34.0	0.225
35.0	0.225
CURVE 22 T = 882.	
2.6	0.719
3.0	0.730
4.0	0.753
5.0	0.773
6.0	0.781
7.0	0.757
8.0	0.719
9.0	0.682
10.0	0.643
11.0	0.597
12.0	0.559
13.0	0.521
14.0	0.503
15.0	0.492
CURVE 23 T = 1074.	
3.6	0.691
4.0	0.712

λ	ε
CURVE 23(CONT.)	
5.0	0.736
6.0	0.746
7.0	0.741
8.0	0.722
9.0	0.684
10.0	0.639
11.0	0.607
12.0	0.575
13.0	0.548
14.0	0.534
15.0	0.517
CURVE 24 T = 300.	
3.0	0.697
4.0	0.746
5.0	0.789
6.0	0.792
7.0	0.669
8.0	0.550
9.0	0.467
10.0	0.406
11.0	0.363
12.0	0.327
13.0	0.307
14.0	0.285
15.0	0.272
16.0	0.258
18.0	0.241
20.0	0.219
22.0	0.208
24.0	0.192
26.0	0.179
28.0	0.168
30.0	0.157
32.0	0.150
34.0	0.147
36.0	0.147

λ	ε
CURVE 25 T = 333.	
3.00	0.009
4.66	0.009
5.49	0.013
5.86	0.024
6.16	0.021
6.39	0.023
6.54	0.031
6.62	0.038
6.70	0.056
6.84	0.088
6.92	0.105
6.98	0.112
7.15	0.103
7.25	0.100
7.33	0.100
7.44	0.106
7.55	0.117
7.64	0.126
7.72	0.130
7.85	0.121
8.05	0.100
8.17	0.100
8.29	0.114
8.41	0.146
8.53	0.179
8.61	0.220
8.72	0.315
8.91	0.522
8.98	0.617
9.05	0.626
9.11	0.619
9.14	0.585
9.29	0.320
9.34	0.245
9.38	0.199
9.42	0.185
9.49	0.167
9.57	0.156
9.77	0.177

TABLE 12-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε
CURVE 25 (CONT.)	
10.00	0.234
10.16	0.272
10.28	0.300
10.31	0.606
10.37	0.310
10.49	0.306
10.59	0.305
10.64	0.313
10.99	0.383
11.09	0.407
11.26	0.419
11.39	0.411
11.76	0.354
11.86	0.348
11.97	0.359
12.07	0.380
12.16	0.405
12.21	0.410
12.25	0.405
12.33	0.393
12.42	0.388
12.50	0.391
12.77	0.425
12.89	0.432
13.19	0.449
13.36	0.464
13.47	0.479
13.50	0.482
CURVE 26	
T = 353.	
3.00	0.009
4.66	0.009
5.49	0.013
5.86	0.024
5.90	0.025
6.13	0.022
6.35	0.024
6.54	0.034

λ	ε
CURVE 26 (CONT.)	
6.63	0.045
6.75	0.071
6.86	0.097
6.91	0.113
6.98	0.117
7.14	0.108
7.23	0.103
7.34	0.103
7.46	0.113
7.59	0.127
7.66	0.132
7.79	0.132
7.88	0.126
7.98	0.112
8.11	0.103
8.22	0.112
8.31	0.124
8.41	0.146
8.53	0.179
8.61	0.220
8.72	0.315
8.91	0.522
8.98	0.617
9.05	0.628
9.11	0.619
9.14	0.585
9.29	0.320
9.34	0.245
9.37	0.252
9.44	0.193
9.51	0.171
9.58	0.162
9.75	0.181
9.97	0.236
10.16	0.278
10.26	0.307
10.35	0.315
10.44	0.315
10.56	0.311
10.83	0.363

λ	ε
CURVE 26 (CONT.)	
11.05	0.409
11.16	0.421
11.26	0.426
11.37	0.421
11.47	0.395
11.81	0.359
11.85	0.359
11.97	0.368
12.13	0.421
12.21	0.429
12.29	0.425
12.32	0.410
12.41	0.401
12.51	0.401
12.61	0.420
12.70	0.437
12.85	0.445
13.11	0.454
13.33	0.467
13.38	0.479
13.48	0.480
13.50	0.486
13.59	0.489
13.81	0.428
14.00	0.332
14.18	0.256
14.33	0.235
14.60	0.230
14.73	0.233
15.00	0.235
CURVE 27	
T = 373.	
3.00	0.009
4.66	0.009
5.49	0.013
5.86	0.024
5.90	0.025
6.13	0.022

λ	ε
CURVE 27 (CONT.)	
6.35	0.024
6.54	0.034
6.63	0.045
6.75	0.071
6.86	0.097
6.94	0.119
7.01	0.127
7.11	0.118
7.23	0.111
7.33	0.111
7.57	0.135
7.69	0.142
7.79	0.142
7.87	0.132
7.99	0.117
8.14	0.114
8.27	0.121
8.37	0.144
8.50	0.180
8.60	0.231
8.72	0.315
8.91	0.522
9.00	0.620
9.08	0.634
9.15	0.626
9.22	0.470
9.35	0.311
9.47	0.207
9.57	0.174
9.71	0.191
9.89	0.224
10.04	0.267
10.22	0.317
10.29	0.329
10.36	0.334
10.47	0.334
10.55	0.331
10.69	0.345
10.86	0.381
10.88	0.399

λ	ε
CURVE 27 (CONT.)	
11.13	0.437
11.24	0.444
11.35	0.445
11.51	0.427
11.81	0.376
11.93	0.376
12.03	0.398
12.11	0.425
12.21	0.436
12.34	0.425
12.38	0.412
12.46	0.412
12.57	0.421
12.73	0.448
12.98	0.464
13.19	0.475
13.35	0.477
13.48	0.487
13.56	0.506
13.70	0.468
14.01	0.343
14.19	0.246
14.28	0.219
14.39	0.214
14.48	0.218
15.00	0.259
CURVE 28	
T = 393.	
3.00	0.015
3.16	0.015
3.23	0.018
3.33	0.018
3.43	0.014
4.99	0.014
5.22	0.018
5.54	0.017
5.84	0.030
6.09	0.028

λ	ε
CURVE 28 (CONT.)	
6.30	0.028
6.44	0.032
6.59	0.044
6.67	0.056
6.87	0.113
6.99	0.131
7.10	0.120
7.22	0.116
7.34	0.116
7.57	0.139
7.67	0.149
7.80	0.149
7.90	0.136
8.04	0.120
8.18	0.120
8.31	0.131
8.48	0.175
8.64	0.245
8.72	0.315
8.88	0.481
8.97	0.601
9.03	0.630
9.10	0.634
9.17	0.621
9.27	0.437
9.44	0.256
9.54	0.197
9.58	0.189
9.82	0.218
10.09	0.283
10.21	0.324
10.28	0.341
10.37	0.346
10.56	0.339
10.72	0.365
10.86	0.398
11.12	0.444
11.23	0.453
11.36	0.453
11.52	0.440

TABLE 12-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE 28 (CONT.)		CURVE 29 (CONT.)		CURVE 29 (CONT.)		CURVE 30 (CONT.)		CURVE 30 (CONT.)		CURVE 31	
11.61	0.424	6.09	0.028	11.17	0.470	3.33	0.019	10.32	0.370	T = 313.	
11.72	0.400	6.30	0.028	11.24	0.476	3.43	0.014	10.39	0.376	3.00	0.029
11.83	0.390	6.44	0.032	11.35	0.477	4.99	0.014	10.46	0.376	3.99	0.022
11.93	0.390	6.59	0.044	11.50	0.467	5.22	0.018	10.53	0.373	4.97	0.017
11.99	0.402	6.67	0.056	11.65	0.441	5.54	0.017	10.63	0.376	5.80	0.018
12.11	0.435	6.87	0.113	11.76	0.420	5.84	0.030	10.83	0.404	5.94	0.021
12.21	0.454	6.93	0.137	11.96	0.415	6.09	0.028	11.09	0.464	6.39	0.021
12.31	0.446	6.98	0.141	12.07	0.435	6.30	0.028	11.17	0.476	6.58	0.031
12.35	0.433	7.07	0.141	12.14	0.467	6.44	0.032	11.29	0.481	6.69	0.042
12.41	0.427	7.18	0.126	12.19	0.473	6.59	0.044	11.37	0.481	6.78	0.060
12.53	0.434	7.33	0.124	12.27	0.474	6.67	0.056	11.54	0.469	6.90	0.075
12.63	0.447	7.49	0.137	12.38	0.467	6.86	0.122	11.63	0.460	7.03	0.088
12.83	0.476	7.69	0.152	12.50	0.467	6.91	0.141	11.76	0.431	7.11	0.088
12.93	0.481	7.76	0.158	12.60	0.475	7.00	0.149	11.83	0.420	7.32	0.081
13.05	0.481	7.99	0.134	12.69	0.485	7.11	0.143	11.96	0.427	7.45	0.090
13.16	0.485	8.09	0.127	12.74	0.502	7.22	0.134	12.10	0.469	7.62	0.105
13.37	0.494	8.25	0.127	12.86	0.506	7.32	0.130	12.14	0.476	7.68	0.105
13.49	0.538	8.34	0.150	13.05	0.506	7.58	0.150	12.26	0.479	7.83	0.088
13.57	0.515	8.46	0.186	13.17	0.515	7.65	0.163	12.34	0.476	7.95	0.079
13.66	0.494	8.54	0.220	13.38	0.523	7.76	0.165	12.54	0.478	8.10	0.079
13.90	0.403	8.62	0.248	13.45	0.537	7.85	0.161	12.62	0.494	8.21	0.083
14.09	0.310	8.72	0.315	13.50	0.549	8.03	0.139	12.70	0.502	8.34	0.099
14.19	0.270	8.88	0.481	13.59	0.549	8.14	0.135	12.82	0.509	8.53	0.136
14.32	0.257	8.96	0.635	13.69	0.531	8.27	0.142	13.02	0.510	8.66	0.180
14.48	0.254	9.01	0.642	13.88	0.474	8.62	0.253	13.37	0.526	8.75	0.226
14.80	0.262	9.07	0.642	14.00	0.397	8.72	0.315	13.45	0.537	8.96	0.331
15.00	0.264	9.14	0.628	14.09	0.323	8.88	0.481	13.54	0.554	9.01	0.382
		9.30	0.393	14.13	0.295	8.94	0.597	13.59	0.557	9.06	0.400
CURVE 29		9.45	0.248	14.23	0.274	9.00	0.627	13.66	0.548	9.13	0.382
T = 413.		9.55	0.210	14.43	0.261	9.09	0.634	13.91	0.474	9.26	0.178
		9.60	0.205	14.58	0.267	9.17	0.625	13.98	0.436	9.31	0.147
3.00	0.015	9.67	0.210	14.86	0.270	9.25	0.509	14.08	0.349	9.43	0.119
3.16	0.015	9.85	0.237	15.00	0.276	9.34	0.393	14.14	0.303	9.51	0.119
3.23	0.018	10.01	0.280			9.46	0.268	14.26	0.278	9.69	0.136
3.33	0.018	10.13	0.313	CURVE 30		9.51	0.234	14.38	0.269	9.94	0.179
3.43	0.014	10.28	0.356	T = 433.		9.58	0.219	14.46	0.269	10.19	0.232
4.99	0.014	10.40	0.368			9.69	0.222	14.60	0.279	10.26	0.247
5.22	0.018	10.49	0.368	3.00	0.015	9.83	0.242	14.74	0.287	10.35	0.256
5.54	0.017	10.62	0.364	3.16	0.015	10.06	0.360	14.82	0.296	10.41	0.256
5.84	0.030	10.75	0.376	3.23	0.018	10.21	0.351	15.00	0.300	10.55	0.251

TABLE 12-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE 31 (CONT.)		CURVE 32 (CONT.)		CURVE 32 (CONT.)		CURVE 33 (CONT.)		CURVE 33 (CONT.)		CURVE 34 (CONT.)	
10.65	0.261	6.91	0.097	11.62	0.336	7.23	0.099	12.47	0.384	7.03	0.133
10.90	0.311	6.97	0.109	11.73	0.322	7.33	0.099	12.56	0.384	7.17	0.123
11.14	0.344	7.05	0.109	11.86	0.312	7.53	0.116	12.66	0.393	7.31	0.110
11.22	0.344	7.18	0.098	11.96	0.316	7.65	0.129	12.70	0.411	7.52	0.132
11.43	0.323	7.23	0.094	12.01	0.324	7.73	0.129	12.78	0.420	7.59	0.139
11.79	0.278	7.34	0.093	12.17	0.361	7.95	0.118	12.91	0.425	7.73	0.144
11.94	0.294	7.64	0.120	12.25	0.369	8.03	0.098	13.05	0.425	7.83	0.138
12.06	0.310	7.71	0.123	12.38	0.352	8.09	0.098	13.14	0.421	8.08	0.111
12.11	0.326	7.85	0.102	12.44	0.348	8.19	0.106	13.25	0.433	8.15	0.113
12.13	0.330	8.00	0.088	12.59	0.358	8.35	0.133	13.51	0.475	8.42	0.163
12.21	0.333	8.14	0.088	12.72	0.374	8.59	0.194	13.58	0.480	8.64	0.225
12.25	0.329	8.20	0.095	12.95	0.387	8.75	0.252	13.63	0.471	8.74	0.267
12.31	0.301	8.53	0.161	13.17	0.405	8.87	0.306	13.95	0.369	8.83	0.314
12.39	0.294	8.67	0.205	13.34	0.405	8.96	0.368	14.05	0.274	8.91	0.366
12.71	0.335	8.80	0.260	13.41	0.415	9.04	0.408	14.14	0.239	8.97	0.407
13.08	0.367	8.90	0.327	13.50	0.430	9.16	0.382	14.22	0.208	9.04	0.413
13.24	0.377	8.96	0.366	13.55	0.434	9.31	0.228	14.36	0.185	9.11	0.407
13.34	0.392	9.00	0.385	13.63	0.426	9.46	0.172	14.43	0.185	9.16	0.397
13.40	0.398	9.05	0.401	13.85	0.323	9.60	0.155	14.51	0.203	9.24	0.331
13.52	0.398	9.15	0.383	14.09	0.224	9.68	0.155	14.63	0.211	9.33	0.269
13.65	0.384	9.20	0.292	14.22	0.172	9.77	0.167	14.77	0.217	9.35	0.244
13.78	0.330	9.25	0.243	14.33	0.175	10.01	0.211	14.85	0.221	9.42	0.216
14.23	0.146	9.32	0.195	14.45	0.175	10.24	0.271	15.00	0.221	9.53	0.187
14.31	0.139	9.37	0.175	14.59	0.173	10.32	0.290			9.60	0.180
14.48	0.139	9.46	0.150	15.00	0.185	10.39	0.298	CURVE 34		9.69	0.183
15.00	0.156	9.55	0.140			10.47	0.301	T = 433.		10.07	0.264
		9.66	0.144	CURVE 33		10.60	0.297			10.25	0.305
CURVE 32		9.82	0.169	T = 393.		10.69	0.302	3.00	0.040	10.34	0.316
T = 353.		10.10	0.224			10.86	0.342	3.99	0.028	10.39	0.322
		10.24	0.253	3.00	0.037	11.00	0.380	4.47	0.024	10.50	0.322
3.00	0.034	10.29	0.272	3.99	0.026	11.25	0.408	5.58	0.024	10.58	0.321
3.98	0.023	10.35	0.282	4.43	0.022	11.37	0.408	6.14	0.028	10.66	0.325
4.37	0.022	10.41	0.282	5.31	0.022	11.48	0.396	6.29	0.030	10.75	0.339
4.99	0.021	10.50	0.273	5.99	0.024	11.69	0.359	6.42	0.036	10.86	0.362
5.73	0.021	10.62	0.279	6.36	0.028	11.86	0.347	6.52	0.042	11.05	0.403
6.00	0.024	10.75	0.301	6.53	0.037	12.00	0.356	6.59	0.052	11.14	0.419
6.41	0.025	11.04	0.355	6.65	0.051	12.09	0.381	6.67	0.069	11.21	0.425
6.55	0.034	11.12	0.369	6.85	0.097	12.13	0.402	6.71	0.089	11.35	0.425
6.66	0.043	11.19	0.382	6.98	0.115	12.29	0.406	6.87	0.120	11.48	0.417
6.86	0.033	11.26	0.386	7.07	0.115	12.41	0.388	6.94	0.129	11.58	0.405

TABLE 12-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, µm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE 34 (CONT.)		CURVE 35 (CONT.)		CURVE 35 (CONT.)		CURVE 36 (CONT.)		CURVE 36 (CONT.)		CURVE 37 (CONT.)	
11.82	0.369	7.08	0.091	12.18	0.338	7.71	0.124	12.25	0.369	7.78	0.131
11.92	0.363	7.18	0.085	12.23	0.329	7.81	0.117	12.34	0.355	8.03	0.100
12.11	0.401	7.32	0.085	12.34	0.296	7.97	0.094	12.44	0.349	8.14	0.100
12.21	0.412	7.50	0.094	12.49	0.311	8.03	0.089	12.77	0.376	8.25	0.112
12.27	0.418	7.61	0.105	12.61	0.327	8.18	0.089	12.97	0.388	8.38	0.138
12.35	0.418	7.72	0.105	12.77	0.344	8.32	0.111	13.17	0.404	8.53	0.173
12.53	0.405	7.82	0.090	12.93	0.357	8.50	0.147	13.32	0.406	8.68	0.214
12.62	0.410	8.00	0.079	13.13	0.368	8.63	0.185	13.41	0.416	8.80	0.264
12.81	0.450	8.17	0.079	13.39	0.397	8.75	0.227	13.47	0.428	8.89	0.323
12.91	0.458	8.35	0.093	13.52	0.397	8.85	0.288	13.52	0.433	8.96	0.380
13.02	0.461	8.50	0.124	13.58	0.390	8.94	0.346	13.59	0.433	8.97	0.399
13.13	0.461	8.63	0.158	13.73	0.353	9.02	0.386	13.67	0.412	9.07	0.407
13.23	0.458	8.74	0.218	13.97	0.243	9.09	0.398	13.90	0.288	9.15	0.397
13.33	0.458	8.94	0.314	14.07	0.199	9.15	0.372	14.17	0.181	9.19	0.379
13.43	0.466	9.05	0.379	14.14	0.181	9.21	0.304	14.23	0.172	9.22	0.319
13.54	0.486	9.09	0.398	14.17	0.157	9.25	0.258	14.40	0.176	9.26	0.279
13.62	0.486	9.13	0.379	14.22	0.148	9.30	0.222	14.56	0.172	9.34	0.228
13.69	0.471	9.18	0.290	14.33	0.141	9.41	0.171	14.80	0.181	9.45	0.186
13.95	0.384	9.27	0.176	14.45	0.141	9.50	0.146	15.00	0.186	9.52	0.170
14.06	0.333	9.31	0.154	15.00	0.160	9.59	0.139			9.58	0.159
14.15	0.284	9.38	0.129			9.69	0.146	CURVE 37		9.66	0.159
14.22	0.239	9.42	0.123	CURVE 36		9.95	0.192	T = 393.		9.79	0.169
14.46	0.212	9.50	0.118	T = 353.		10.15	0.238			10.08	0.227
14.82	0.187	9.62	0.125			10.21	0.252	3.00	0.039	10.32	0.295
14.89	0.187	9.86	0.156	3.00	0.038	10.24	0.273	3.93	0.030	10.43	0.302
15.00	0.194	10.05	0.198	3.82	0.029	10.35	0.283	4.45	0.025	10.52	0.298
		10.13	0.222	4.39	0.025	10.43	0.283	4.75	0.024	10.61	0.298
CURVE 35		10.29	0.250	4.97	0.022	10.51	0.275	5.42	0.024	10.72	0.307
T = 313.		10.36	0.258	5.46	0.022	10.60	0.275	5.67	0.025	10.80	0.329
		10.44	0.258	5.74	0.026	10.80	0.305	5.86	0.030	10.91	0.365
3.00	0.035	10.54	0.254	5.92	0.029	10.99	0.353	6.24	0.030	11.18	0.403
3.73	0.025	10.55	0.260	6.26	0.029	11.14	0.367	6.41	0.032	11.26	0.410
4.83	0.018	10.97	0.315	6.43	0.032	11.22	0.384	6.55	0.040	11.38	0.410
9.49	0.018	11.09	0.336	6.61	0.046	11.32	0.384	6.66	0.052	11.52	0.390
5.78	0.023	11.21	0.342	6.79	0.064	11.71	0.329	6.83	0.089	11.66	0.360
6.37	0.023	11.33	0.331	6.95	0.099	11.83	0.313	6.95	0.112	11.77	0.349
6.54	0.029	11.80	0.280	7.04	0.109	11.95	0.313	7.04	0.121	11.91	0.348
6.71	0.045	11.94	0.293	7.25	0.095	12.07	0.328	7.21	0.105	12.03	0.364
6.87	0.066	12.07	0.312	7.36	0.095	12.11	0.339	7.38	0.105	12.20	0.398
6.97	0.082	12.15	0.330	7.47	0.104	12.13	0.354	7.65	0.131	12.29	0.407

TABLE 12-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε
CURVE 37 (CONT.)	
12.46	0.383
12.60	0.383
12.68	0.396
12.73	0.414
12.80	0.422
12.99	0.426
13.14	0.423
13.28	0.436
13.41	0.453
13.51	0.473
13.57	0.481
13.66	0.471
13.83	0.400
13.95	0.359
14.03	0.284
14.14	0.234
14.21	0.214
14.34	0.190
14.44	0.190
14.50	0.207
14.64	0.217
14.77	0.223
15.80	0.225
CURVE 38	
T = 433.	
3.00	0.041
3.52	0.035
4.32	0.029
4.55	0.025
5.42	0.025
5.86	0.031
6.20	0.031
6.37	0.034
6.48	0.039
6.59	0.048
6.65	0.058
6.80	0.100
6.90	0.121

λ	ε
CURVE 38 (CONT.)	
7.01	0.133
7.10	0.133
7.26	0.113
7.35	0.113
7.69	0.144
7.79	0.144
7.98	0.126
8.13	0.112
8.28	0.126
8.44	0.160
8.62	0.214
8.70	0.235
8.88	0.331
8.98	0.402
9.05	0.414
9.14	0.409
9.20	0.393
9.33	0.274
9.49	0.206
9.61	0.180
9.69	0.180
9.80	0.195
10.08	0.255
10.24	0.296
10.34	0.319
10.54	0.319
10.70	0.332
10.81	0.348
10.95	0.379
11.04	0.400
11.23	0.425
11.32	0.425
11.50	0.416
11.86	0.365
11.96	0.368
12.22	0.415
12.28	0.419
12.37	0.419
12.46	0.406
12.54	0.402

λ	ε
CURVE 38 (CONT.)	
12.61	0.409
12.72	0.436
12.80	0.451
12.99	0.459
13.14	0.459
13.30	0.456
13.36	0.460
13.54	0.487
13.60	0.488
13.66	0.480
13.88	0.401
14.00	0.355
14.07	0.306
14.22	0.246
14.33	0.224
14.47	0.211
14.64	0.202
14.83	0.188
15.00	0.195
CURVE 39	
T = 543.	
0.398	0.525
0.473	0.580
0.528	0.601
0.610	0.625
0.681	0.637
0.820	0.655
0.929	0.672
1.127	0.672
1.175	0.660
1.208	0.629
1.262	0.353
1.300	0.258
1.337	0.176
1.390	0.130
1.459	0.0980
1.549	0.0810
1.656	0.0670

λ	ε
CURVE 39 (CONT.)	
1.837	0.0530
2.291	0.0530
2.500	0.0560
3.724	0.0620
5.117	0.0680
5.975	0.0750
6.281	0.0860
6.531	0.0980
6.699	0.154
6.823	0.180
6.982	0.205
7.129	0.205
7.195	0.190
7.499	0.179
7.638	0.201
7.962	0.179
8.260	0.154
8.511	0.185
8.730	0.324
8.974	0.434
9.141	0.454
9.376	0.384
9.376	0.329
9.818	0.293
10.00	0.314
11.00	0.430
12.00	0.449
13.00	0.498
14.00	0.558
15.00	0.460
CURVE 40	
T = 623.	
0.398	0.525
0.473	0.580
0.528	0.601
0.610	0.625
0.681	0.637
0.820	0.655

λ	ε
CURVE 40 (CONT.)	
0.929	0.672
1.04	0.675
1.18	0.675
1.21	0.659
1.23	0.631
1.26	0.506
1.29	0.361
1.34	0.272
1.39	0.207
1.45	0.163
1.60	0.132
1.72	0.119
1.88	0.112
2.14	0.112
2.31	0.118
2.90	0.130
3.61	0.148
4.56	0.166
5.05	0.179
5.55	0.199
6.03	0.224
6.37	0.248
6.56	0.270
6.71	0.289
6.79	0.307
6.89	0.319
7.03	0.319
7.28	0.305
7.83	0.356
8.00	0.356
8.34	0.391
8.61	0.441
8.97	0.507
9.14	0.521
9.31	0.508
9.51	0.467
9.73	0.454
10.00	0.470
11.00	0.549
12.00	0.583

λ	ε
CURVE 40 (CONT.)	
13.00	0.596
14.00	0.631
15.00	0.569
CURVE 41	
T = 693.	
0.398	0.525
0.473	0.580
0.528	0.601
0.610	0.625
0.681	0.637
0.820	0.655
0.929	0.672
1.04	0.675
1.21	0.674
1.25	0.657
1.26	0.632
1.28	0.594
1.30	0.427
1.33	0.348
1.37	0.278
1.41	0.229
1.44	0.202
1.66	0.186
1.88	0.186
2.00	0.195
3.04	0.258
3.67	0.300
5.05	0.378
6.11	0.435
8.11	0.529
8.91	0.563
9.00	0.564
10.00	0.597
11.00	0.647
12.00	0.680
13.00	0.703
14.00	0.712
15.00	0.710

TABLE 12-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε
CURVE 42	
T = 743.	
0.398	0.525
0.473	0.580
0.528	0.601
0.610	0.625
0.681	0.637
0.820	0.655
0.929	0.672
1.04	0.675
1.21	0.674
1.25	0.661
1.29	0.641
1.31	0.616
1.32	0.484
1.34	0.416
1.37	0.372
1.42	0.350
1.51	0.339
1.58	0.342
2.13	0.396
2.84	0.452
3.48	0.498
4.30	0.553
4.97	0.594
5.66	0.627
6.37	0.651
7.23	0.675
8.38	0.698
9.25	0.708
10.00	0.712
11.00	0.716
12.00	0.716
13.00	0.713
14.00	0.712
15.00	0.710
CURVE 43	
T = 793.	
0.398	0.500
CURVE 43 (CONT.)	
0.443	0.546
0.479	0.569
0.530	0.591
0.592	0.611
0.655	0.622
0.813	0.647
0.887	0.656
1.04	0.673
1.20	0.676
1.25	0.670
1.31	0.652
1.35	0.622
1.37	0.549
1.39	0.479
1.43	0.442
1.52	0.429
1.73	0.451
2.15	0.517
2.54	0.558
2.94	0.594
3.37	0.622
4.06	0.653
4.70	0.675
5.47	0.695
6.47	0.710
7.28	0.717
8.00	0.716
9.00	0.716
10.00	0.716
11.00	0.716
12.00	0.716
13.00	0.713
14.00	0.712
15.00	0.710
CURVE 44	
T = 873.	
0.398	0.484
0.454	0.540
CURVE 44 (CONT.)	
0.494	0.567
0.535	0.589
0.601	0.608
0.638	0.615
0.733	0.631
0.855	0.650
1.00	0.664
1.22	0.677
1.69	0.693
2.24	0.706
3.01	0.714
4.88	0.716
5.00	0.716
6.00	0.716
7.00	0.716
8.00	0.716
9.00	0.716
10.00	0.716
11.00	0.716
12.00	0.716
13.00	0.713
14.00	0.712
15.00	0.710
CURVE 45	
T = 1073.	
0.398	0.463
0.433	0.508
0.463	0.533
0.496	0.558
0.542	0.580
0.592	0.597
0.638	0.615
0.733	0.631
0.855	0.650
1.00	0.664
1.22	0.677
1.69	0.693
2.24	0.706
CURVE 45 (CONT.)	
3.01	0.714
4.88	0.716
5.00	0.716
6.00	0.716
7.00	0.716
8.00	0.716
9.00	0.716
10.00	0.716
11.00	0.716
12.00	0.716
13.00	0.713
14.00	0.712
15.00	0.710
CURVE 46	
T = 543.	
2.98	0.686
3.55	0.689
4.11	0.694
4.56	0.702
5.02	0.708
6.05	0.722
6.99	0.735
8.05	0.749
9.12	0.762
10.14	0.771
11.14	0.786
12.33	0.795
13.34	0.802
14.22	0.805
CURVE 47	
T = 693.	
2.98	0.683
3.55	0.686
4.11	0.691
4.60	0.697
5.07	0.702
CURVE 47 (CONT.)	
6.18	0.717
7.05	0.730
8.11	0.747
9.12	0.758
10.16	0.766
11.14	0.782
12.33	0.789
13.33	0.794
14.22	0.798
CURVE 48	
T = 793.	
2.98	0.675
3.57	0.677
4.15	0.684
4.58	0.688
5.14	0.697
6.28	0.710
7.13	0.721
8.22	0.735
9.27	0.748
10.23	0.755
11.14	0.766
12.33	0.777
13.34	0.781
14.22	0.784
CURVE 49	
T = 893.	
2.98	0.662
3.57	0.666
4.18	0.671
4.69	0.678
5.27	0.686
6.38	0.703
7.13	0.711
8.34	0.727
9.48	0.739
CURVE 49 (CONT.)	
10.23	0.748
11.14	0.756
12.33	0.761
13.34	0.766
14.22	0.766
CURVE 50	
T = 543.	
2.26	0.684
3.01	0.688
4.06	0.699
5.01	0.709
5.98	0.719
7.11	0.730
7.93	0.737
8.97	0.747
10.00	0.755
11.09	0.767
12.16	0.776
13.21	0.781
14.03	0.783
15.14	0.786
CURVE 51	
T = 893.	
2.44	0.665
3.01	0.669
4.06	0.677
5.01	0.688
5.98	0.696
7.11	0.709
7.93	0.717
8.97	0.726
10.00	0.732
11.09	0.742
12.16	0.745
13.21	0.734
14.03	0.749

b. Normal Spectral Emittance (Temperature Dependence)

Only five papers have reported the normal spectral emittance of high purity silicon at higher than room temperatures. Only three of the five have reported measurements in the 1-15 μm range. The available experimental data, covering a temperature range from 300-1075 K, are shown in Figure 12-5 and Table 12-6. The data of curves 5 through 18 were obtained by reading points from the spectral curves of Section 12.4.a at the selected wavelengths of 2.8, 3.8, 5.0, and 10.6 μm.

The recommended values shown in Table 12-4 and Figure 12-4 are based on the data of Sato [T41640] (curves 11-14) at temperatures above 550 K and on the data of Stierwalt [T16961] (curves 5-10) and Stierwalt and Potter [T32537] (curves 15-18) below 550 K. The samples used by Stierwalt and Stierwalt and Potter were high resistivity, 2.03 mm thick (n-type) and 1.68 mm thick (p-type) single crystals, while Sato's sample was a 1.77 mm thick, n-type single crystal. The tabulated values for the selected wavelengths were obtained by drawing an average curve through the data for the 2.03 and 1.68 mm thick samples in the 300-550 K range and smoothly joining it to the higher temperature data for the 1.77 mm thick sample. Consequently, at the lower temperatures, the tabulated values are applicable only to samples about 2 mm thick. However, at temperatures above about 800 K, silicon of ordinary purity becomes opaque to radiation in the 2-15 μm range and the normal spectral emittance no longer depends on the thickness of the sample. Above about 800 K, therefore, the tabulated values are applicable to polished high resistivity, single crystals of any thickness. In this temperature region, the emittance converges to a value of about 0.710 for all wavelengths in the 2-15 μm region. Sato's measurements show that this value does not vary significantly with increasing temperature in the 900-1100 K range. Assuming that this trend continues, the constant-valued curves have been extended, provisionally, to 1600 K.

The 0.710 value of the emittance for opaque specimens gives a value of 0.290 for the single surface reflectance. As mentioned in the previous section, a variety of experimental evidence confirms a value of 0.30 for the single surface reflectance of polished relatively pure silicon at room temperature for 2-15 μm radiation. This supports the high temperature emittance values, if the single surface reflectance does not vary greatly with temperature. Measurements of the absorption coefficient and refractive index at high temperatures indicate that the single surface reflectance does indeed maintain a value near 0.30 at high temperatures.

The tabulated values for 2.8, 3.8, and 5.0 μm in the 300-700 K range must be considered typical only. Their percentage uncertainty is high (as great as 80-90%) both

because of the method used to generate them and because the emittance is very small in this range. The uncertainty of the values for 10.6 μm radiation should not exceed ± 15% in the 300-700 K range. From 800-1100 K, the uncertainty of the values for all wavelengths is believed to be no greater than ± 8%. From 1100-1600 K, the values are extrapolated, but should be accurate to within 30%.

TABLE 12-4. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF HIGH RESISTIVITY SILICON (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

T	ε	T	ε	T	ε	T	ε
SINGLE CRYSTAL 2 MM THICK λ = 2.8		SINGLE CRYSTAL 2 MM THICK λ = 3.8		SINGLE CRYSTAL 2 MM THICK λ = 5.0		SINGLE CRYSTAL 2 MM THICK λ = 10.6	
300.	0.0288†	300.	0.0128†	300.	0.0118†	300.	0.265
350.	0.0328	350.	0.0178	350.	0.0153	325.	0.280
400.	0.0378	400.	0.0218	400.	0.0198	350.	0.296
425.	0.0398	425.	0.0238	425.	0.0218	375.	0.313
450.	0.0418	450.	0.0258	450.	0.0248	400.	0.330
475.	0.0428	475.	0.0289	475.	0.0279	425.	0.346
500.	0.0458	500.	0.0369	500.	0.0378	450.	0.364
520.	0.0498	520.	0.0458	520.	0.0498	475.	0.382
540.	0.0568	540.	0.0598	540.	0.0659	500.	0.400
560.	0.069A	560.	0.074A	560.	0.085A	525.	0.419
580.	0.087A	580.	0.092A	580.	0.109A	550.	0.440
600.	0.106A	600.	0.114A	600.	0.138A	575.	0.464
620.	0.126	620.	0.138	620.	0.173	600.	0.490
640.	0.151	640.	0.169	640.	0.217	620.	0.517
660.	0.181	660.	0.206	660.	0.270	640.	0.538
680.	0.213	680.	0.253	680.	0.333	660.	0.568
700.	0.262	700.	0.314	700.	0.404	680.	0.609
720.	0.344	720.	0.393	720.	0.490	690.	0.630
740.	0.431	740.	0.487	740.	0.581	700.	0.652
760.	0.499	760.	0.560	760.	0.634	710.	0.672
780.	0.559	780.	0.610	780.	0.664	720.	0.689
800.	0.608	800.	0.649	800.	0.685	730.	0.700
820.	0.647	820.	0.678	820.	0.699	740.	0.710
840.	0.682	840.	0.698	840.	0.709	750.	0.714
860.	0.705	860.	0.711	860.	0.715	800.	0.716
880.	0.712	880.	0.714	880.	0.716	850.	0.716
900.	0.712	900.	0.714	900.	0.716	900.	0.716
950.	0.712	950.	0.714	950.	0.716	950.	0.716
1000.	0.712	1000.	0.714	1000.	0.716	1000.	0.716
1050.	0.712	1050.	0.714	1050.	0.716	1050.	0.716
1075.	0.712	1075.	0.714	1075.	0.716	1075.	0.716
1400.	0.712A	1400.	0.714A	1400.	0.716A	1400.	0.716A
1600.	0.712A	1600.	0.714A	1600.	0.716A	1600.	0.716A

† VALUE FOLLOWED BY AN "A" IS PROVISIONAL AND BY A "B" IS TYPICAL.

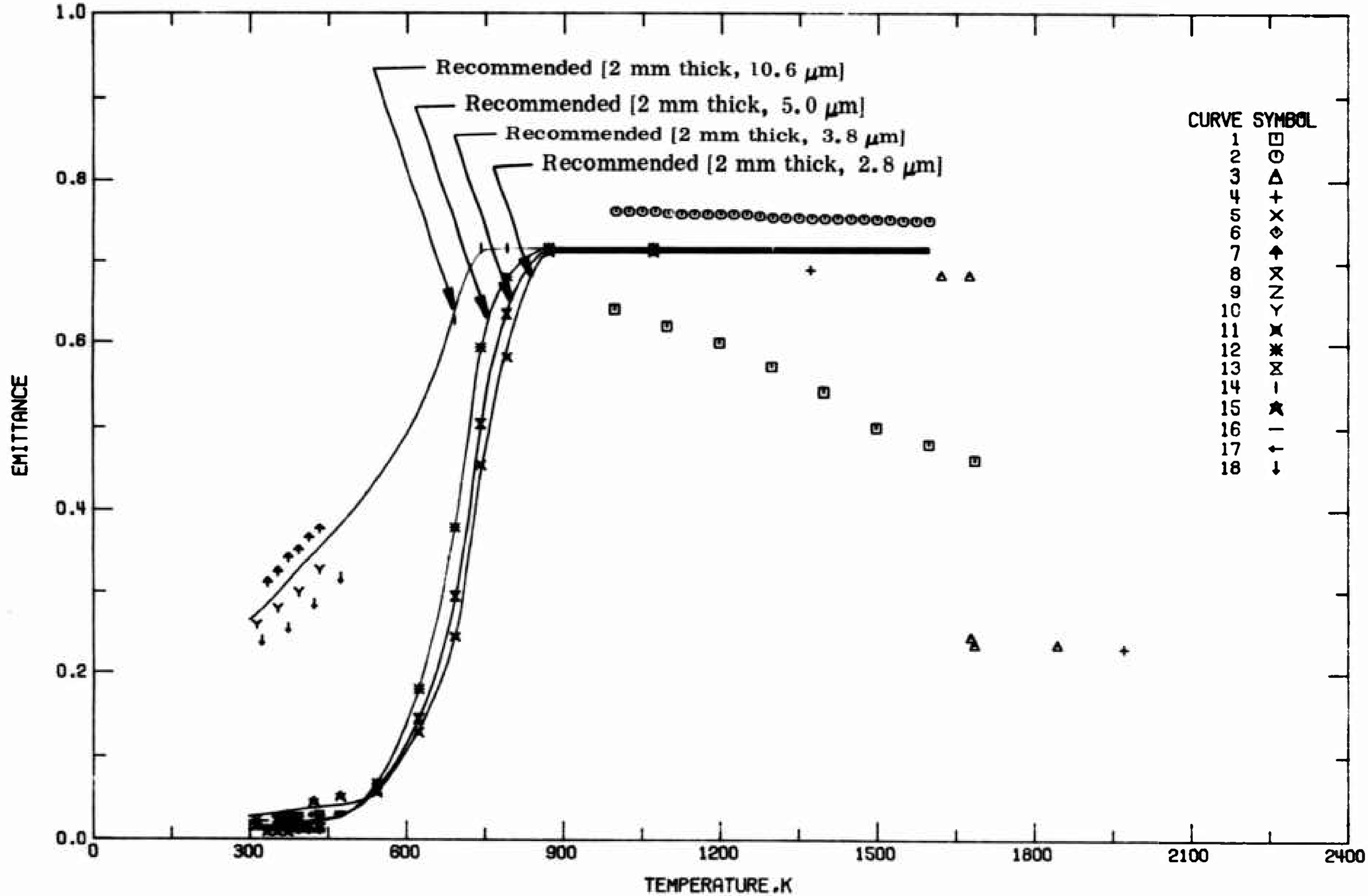


FIGURE 12-4. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF HIGH-RESISTIVITY SILICON (TEMPERATURE DEPENDENCE)

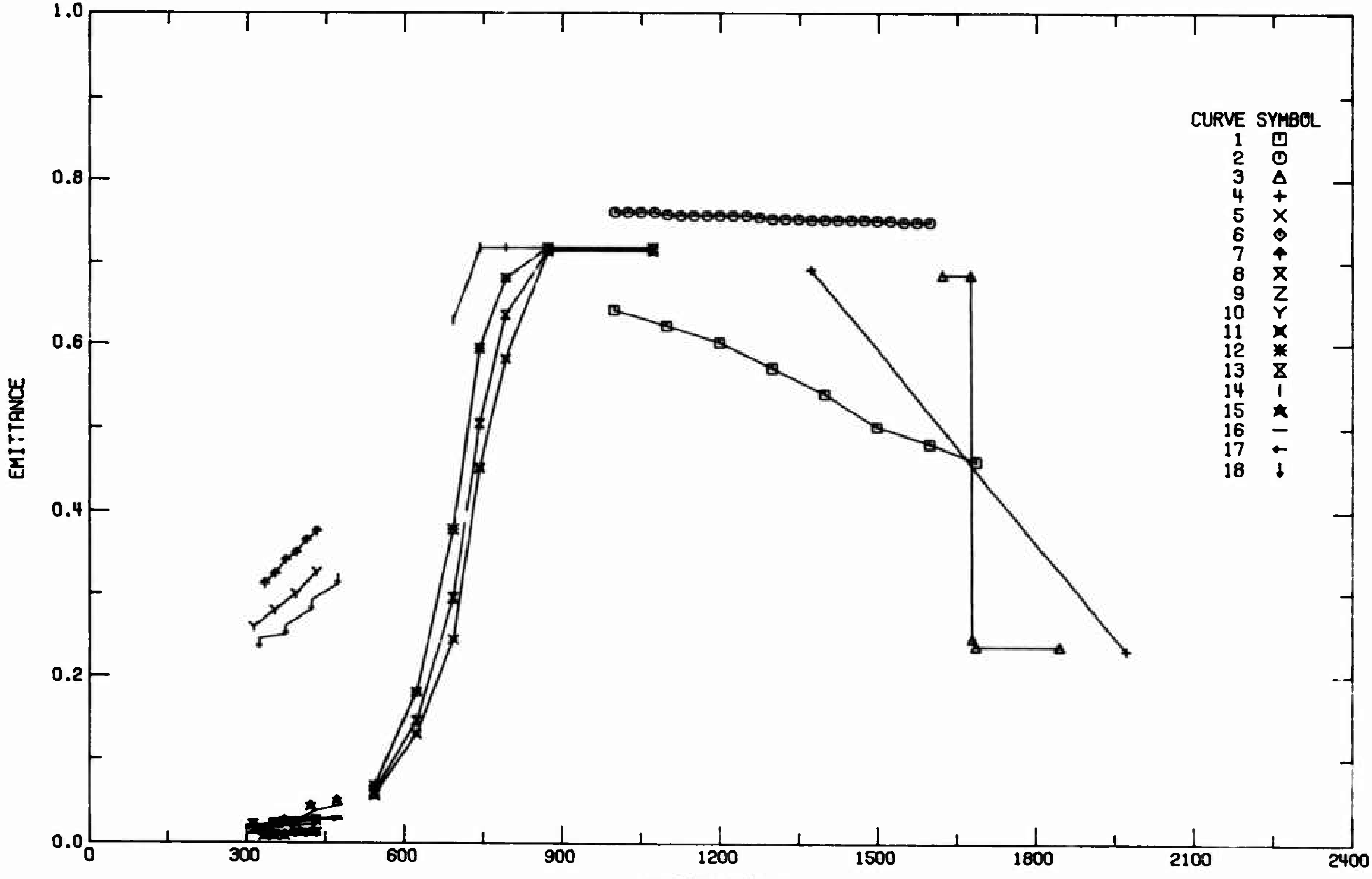


FIGURE 12-5. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON (TEMPERATURE DEPENDENCE)

TABLE 12-5. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMISSIVITY OF SILICON (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, µm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1*	T8677	Allen, F.G.	1957	0.65	1000-1688		Single crystal; long thin-walled cylinder 1 in. long x 0.5 in. O.D. x 0.020 in. wall; etched; vacuum of 10^{-7} to 10^{-9} mm Hg; Worthing thin-walled cylinder technique; geometry gave as much as 5% less than ideal black body conditions; values may be high, particularly at lower temperatures; reported error ± 10%.
2*	T8677	Allen, F.C.	1957	0.65	1000-1688		Similar to the above specimen except specimen sandblasted and measured in open air; rough indication only; extracted from smoothed curve.
3*	T74089	Baum, B.A., Shvarev, K.M., and Gel'd, P.V.	1971	0.72			Values obtained by comparing spectral intensities from the liquid specimen and from simulated graphite black body.
4*	T74089	Baum, B.A., et al.	1971	0.66	1373, 1973		Similar to the above specimen.
5	T16961	Stierwalt, D.L.	1961	3.8	333-433		n-type, single crystal; 2.03 mm thick; both surfaces ground and polished; measured in vacuum using modified Beckman IR-3 spectrophotometer; resistivity 30-60 ohm-cm; data extracted from spectral curves roughly.
6	T16961	Stierwalt, D.L.	1961	5.0	333-433		The above specimen.
7	T16961	Stierwalt, D.L.	1961	10.6	333-433		The above specimen.
8	T16961	Stierwalt, D.L.	1961	3.8	313-433		p-type, single crystal; 1.68 mm thick; ground and polished on both surfaces; measured in vacuum using modified Beckman IR-3 spectrophotometer; data extracted from spectral curves.
9	T16961	Stierwalt, D.L.	1961	5.0	313-433		The above specimen.
10	T16961	Stierwalt, D.L.	1961	10.6	313-433		The above specimen.
11	T41640	Sato, T.	1967	2.8	543-1073		n-type, phosphorous doped, single crystal disk with 28 mm diameter and 1.77 mm thickness; resistivity 15 ohm-cm; ground and polished plane parallel using metallographic and optical techniques; measured under 10^{-4} mm Hg to preclude oxidation; data extracted from spectral curves.
12	T41640	Sato, T.	1967	5.0	543-1073		The above specimen.
13	T41640	Sato, T.	1967	3.8	543-1073		The above specimen.
14	T41640	Sato, T.	1967	10.6	543-1073		The above specimen.
15	T32537	Stierwalt, D.L. and Potter, R.F.	1962	2.8	323-473		p-type, single crystal; 1.68 mm thick; resistivity 30 ohm-cm; cut to size with ultrasonic tool; optical surfaces prepared using standard lapping and polishing techniques; not etched; data extracted from spectral curves.
16	T32537	Stierwalt, D.L. and Potter, R.F.	1962	3.8	323-473		The above specimen.
17	T32537	Stierwalt, D.L. and Potter, R.F.	1962	5.0	323-473		The above specimen.
18	T32537	Stierwalt, D.L. and Potter, R.F.	1962	10.6	323-473		The above specimen.

* Not shown in figure.

TABLE 12-6. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF HIGH RESISTIVITY SILICON (TEMPERATURE DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

T	ε
CURVE 1 λ = 0.65	
1000.	0.64
1100.	0.62
1200.	0.60
1300.	0.57
1400.	0.54
1500.	0.50
1600.	0.48
1688.	0.46
CURVE 2 λ = 0.65	
1000.	0.759
1025.	0.759
1050.	0.759
1075.	0.759
1100.	0.756
1125.	0.755
1150.	0.755
1175.	0.755
1200.	0.755
1225.	0.755
1250.	0.755
1275.	0.753
1300.	0.751
1325.	0.751
1350.	0.751
1375.	0.750
1400.	0.750
1425.	0.750
1450.	0.750
1475.	0.750
1500.	0.749
1525.	0.749
1550.	0.747
1575.	0.747
1600.	0.747

T	ε
CURVE 3 λ = 0.72	
1623.	0.684
1677.	0.684
1680.	0.245
1687.	0.235
1846.	0.235
CURVE 4 λ = 0.66	
1373.	0.69
1973.	0.23
CURVE 5 λ = 3.8	
333.	0.009
353.	0.009
373.	0.0[illegible]
393.	0.014
413.	0.014
433.	0.014
CURVE 6 λ = 5.0	
333.	0.011
353.	0.011
373.	0.011
393.	0.012
413.	0.012
433.	0.012
CURVE 7 λ = 10.6	
333.	0.310
353.	0.322
373.	0.339
393.	0.349

T	ε
CURVE 7 (CONT.)	
413.	0.365
433.	0.376
CURVE 8 λ = 3.8	
313.	0.023
353.	0.024
393.	0.026
433.	0.028
CURVE 9 λ = 5.0	
313.	0.017
353.	0.021
393.	0.022
433.	0.024
CURVE 10 λ = 10.6	
313.	0.258
353.	0.279
393.	0.298
433.	0.324
CURVE 11 λ = 2.8	
543.	0.057
623.	0.128
693.	0.243
743.	0.453
793.	0.581
873.	0.712
1073.	0.712

T	ε
CURVE 12 λ = 5.0	
543.	0.067
623.	0.179
693.	0.378
743.	0.593
793.	0.680
873.	0.716
1073.	0.716
CURVE 13 λ = 3.8	
543.	0.061
623.	0.144
693.	0.294
743.	0.504
793.	0.634
873.	0.714
1073.	0.714
CURVE 14 λ = 10.6	
693.	0.627
743.	0.716
793.	0.716
873.	0.716
1073.	0.716
CURVE 15 λ = 2.8	
373.	0.029
423.	0.046
473.	0.052
CURVE 16 λ = 3.8	
323.	0.022

T	ε
CURVE 16 (CONT.)	
373.	0.026
423.	0.028
473.	0.033
CURVE 17 λ = 5.0	
323.	0.016
373.	0.022
423.	0.030
473.	0.030
CURVE 18 λ = 10.6	
323.	0.238
373.	0.254
423.	0.285
473.	0.315

c. Normal Spectral Reflectance (Wavelength Dependence)

Twenty-four experimental data sets for the wavelength dependence (1-14 μm) of the normal spectral reflectance of silicon are shown in Table 12-9 and Figure 12-7. All of the measurements were made at room temperature for single crystal specimens. Of the 24 data sets, 8 sets are for specimens of relatively high purity.

The recommended values for 330 K shown in Table 12-7 and Figure 12-6 were calculated from the recommended values for the normal spectral emittance at 330 K by use of the McMahon [T20468] relations (Eq. 2.6-10 to 2.6-12). Equation 2.6-12 for the normal spectral emittance, ϵ, can be rearranged to yield

$$ad = \ln\left(\frac{1 - R - R\epsilon}{1 - \epsilon - R}\right) \qquad (4.12\text{-}1)$$

where a is the absorption coefficient, d is the thickness, and R is the single surface reflectance of a plane-parallel specimen. As discussed in the previous sections, the single surface reflectance (i.e., the reflectance of an opaque specimen) of silicon near room temperature is 0.30 in the 2-15 μm range. Using this value, and the recommended emittance values, ad was calculated from Eq. 4.12-1 and used in the McMahon relation (Eq. 2.6-11) to determine the normal spectral reflectance. The 330 K values are applicable to a 2 mm thick, silicon single crystal of relatively high purity and resistivity.

In the 1.5-8 μm wavelength range, the 330 K recommended values agree with the data of Vasilev, et al. [T49418] (curve 24) and Fray, et al. [T41607] (curves 20, 21) to within 5% and with the data of Sato [T41640] (curve 22) to within 10%. These investigators did not specify the thickness of their samples. In this wavelength range, the normal spectral emittance is quite low and the normal spectral reflectance approaches the 0.46 value predicted by the McMahon relations for negligible absorption and emission. It is worthwhile to note that the 0.46 value is accurate to within 15% for any specimen whose emittance is 0.20 or less. According to measurements by Stierwalt [T32537] (curves 8, 9 of Section 4.12.a), this criteria is satisfied in the 2-6.5 μm range by specimens as thick as 13 mm, so the recommended values are applicable to a rather wide range of thicknesses in the 2-6.5 μm range. In the 1.5-8 μm range, the uncertainty of the 330 K recommended values should not exceed ± 10%. In the 8-14 μm wavelength range, there is no experimental reflectance data which can be meaningfully compared with the recommended values. However, the uncertainty of the values in this range is believed to be no greater than ± 15%. The uncertainty may be greater in the 9 μm region due to differences between crystals in the bulk oxygen content.

The 1075 K recommended values were obtained from the normal spectral emittance data of Sato [T41640] (curve 45 of Section 4.12.a). Silicon of ordinary purity is opaque in the 2-15 μm region at this high temperature, because of absorption due to free carriers, and the sum of the normal spectral emittance and the normal spectral reflectance is unity. The values are applicable to plane-parallel, polished, silicon single crystals of relatively high purity and of any thickness. The uncertainty of the 1075 K recommended values is believed to be within $\pm 10\%$ in the 2-15 μm wavelength range.

For applications as infra-red optical components, silicon is often coated with other materials designed to reduce reflection losses in specified wavelength ranges. The thermal radiative properties of these systems of silicon plus anti-reflection coatings may be markedly different from those of silicon alone. Surface oxide layers produced by high temperature atmospheric heating of silicon also alter the reflectance properties, as shown by curves 22 and 23 by Sato [T41640].

The reflectance of silicon may change greatly when it is strongly excited by laser radiation. Bobrova, et al. [T76806] measured the reflectance at 10.6 μm of a high resistivity silicon specimen under excitation by a ruby laser (0.6943 μm). They found that the reflectance first decreased from 0.30 to 0.19, and then increased to 0.50 as the excitation intensity was increased. The minimum reflectance occurred at an excitation intensity of about 10^{24} kW cm^{-2} s^{-1}. Birnbaum and Stocker [A000029] found that the reflectance at around 0.5 μm (argon-ion laser) of a silicon specimen under excitation by a ruby laser increased by as much as 60%. Other investigators [A000031, T77096, T36227, T35800, T36304] have observed similar changes in silicon and other semiconductors. Gauster and Bushnell [T37021] and Reintjes and McGroddy [T77510] have observed related increases in the absorption of silicon when excited by laser radiation. These effects have been attributed both to the presence of a thin metallic surface layer produced by melting and to the presence of a high concentration of non-equilibrium charge carriers generated by the laser radiation.

TABLE 12-7. RECOMMENDED NORMAL SPECTRAL REFLECTANCE OF HIGH RESISTIVITY SILICON (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ	λ	ρ	λ	ρ	λ	ρ
SINGLE CRYSTAL 2.0 MM THICK T = 330		SINGLE CRYSTAL 2.0 MM THICK T = 330 (CONT.)		SINGLE CRYSTAL 2.0 MM THICK T = 330 (CONT.)		SINGLE CRYSTAL OPAQUE T = 1075	
1.00	0.335B†	8.20	0.426	12.10	0.343	1.00	0.336A†
1.10	0.420B	8.30	0.422	12.20	0.339	1.50	0.313A
1.20	0.446B	8.40	0.412	12.30	0.341	2.00	0.303A
1.30	0.453	8.50	0.401A†	12.40	0.343	2.80	0.288
1.40	0.456	8.60	0.389A	12.50	0.342	3.00	0.286
1.50	0.457	8.70	0.371A	12.60	0.340	3.80	0.286
1.60	0.457	8.80	0.348A	12.70	0.338	4.00	0.286
1.70	0.457	8.90	0.332A	12.80	0.334	4.50	0.285
1.80	0.458	9.00	0.325A	12.90	0.333	5.00	0.284
1.90	0.458	9.10	0.325A	13.00	0.332	6.00	0.284
2.00	0.458	9.20	0.336A	13.10	0.331	7.00	0.284
2.20	0.458	9.30	0.360A	13.20	0.329	8.00	0.284
2.40	0.458	9.40	0.399	13.30	0.327	9.00	0.284
2.60	0.458	9.50	0.406	13.40	0.325	10.00	0.284
2.80	0.458	9.60	0.408	13.50	0.323	10.60	0.284
3.00	0.458	9.70	0.405	13.60	0.324	11.00	0.284
3.80	0.458	9.80	0.398	13.70	0.330	12.00	0.284
4.00	0.458	9.90	0.392	13.80	0.337	13.00	0.287
5.00	0.458	10.00	0.385	13.90	0.348	14.00	0.288
5.50	0.457	10.10	0.377	14.00	0.363	15.00	0.290
5.85	0.453	10.20	0.370				
6.00	0.454	10.30	0.364				
6.20	0.454	10.40	0.363				
6.40	0.453	10.50	0.364				
6.60	0.446	10.60	0.364				
6.80	0.433	10.70	0.358				
6.90	0.425	10.80	0.353				
7.00	0.423	10.90	0.347				
7.10	0.426	11.00	0.342				
7.20	0.427	11.10	0.338				
7.30	0.427	11.20	0.336				
7.40	0.426	11.30	0.336				
7.50	0.422	11.40	0.338				
7.60	0.419	11.50	0.342				
7.70	0.417	11.60	0.346				
7.80	0.420	11.70	0.350				
7.90	0.423	11.80	0.352				
8.00	0.426	11.90	0.352				
8.10	0.427	12.00	0.348				

†VALUE FOLLOWED BY AN "A" IS PROVISIONAL AND BY A "B" IS TYPICAL.

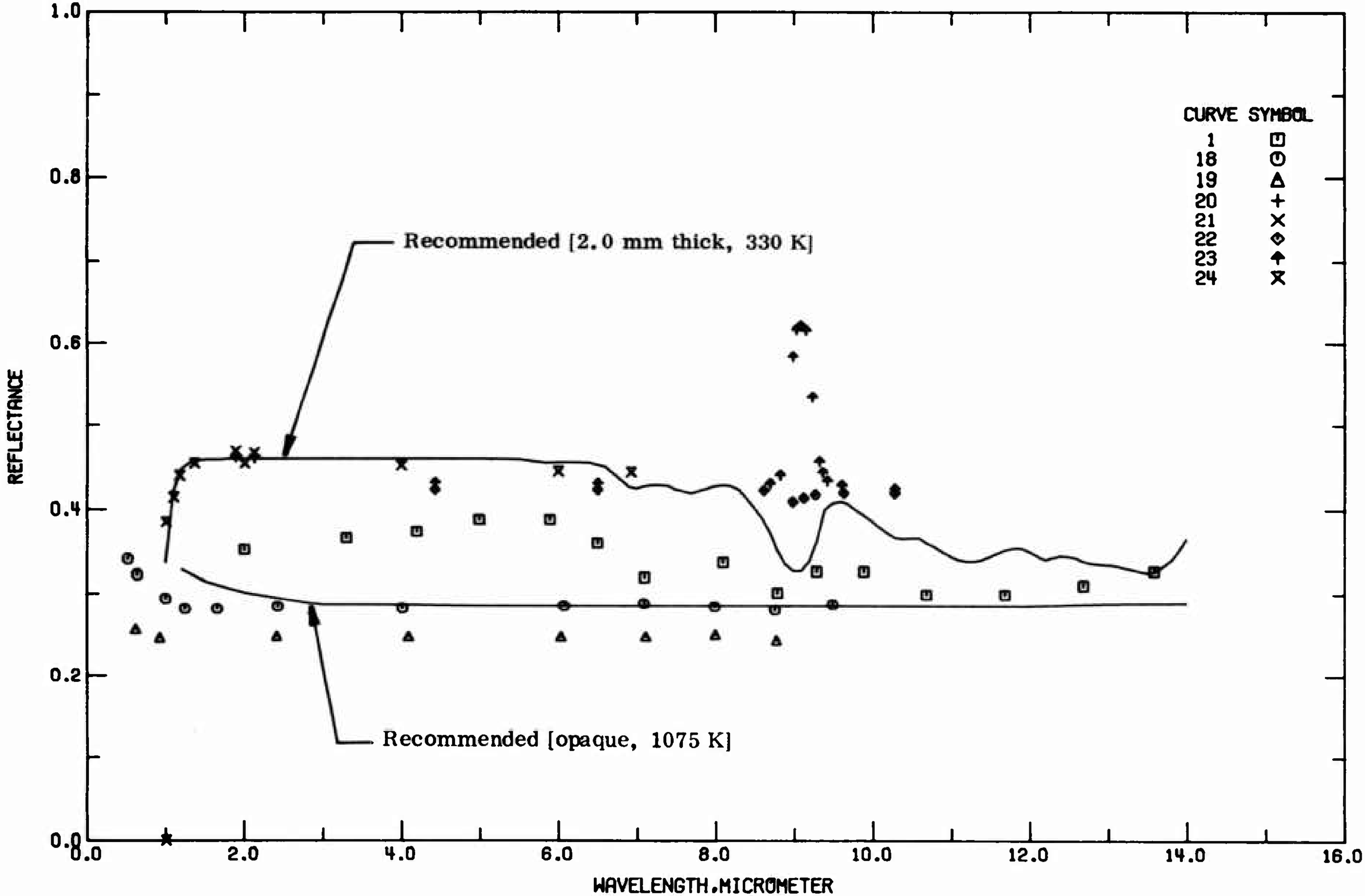


FIGURE 12-6. RECOMMENDED NORMAL SPECTRAL REFLECTANCE OF HIGH-RESISTIVITY SILICON (WAVELENGTH DEPENDENCE)

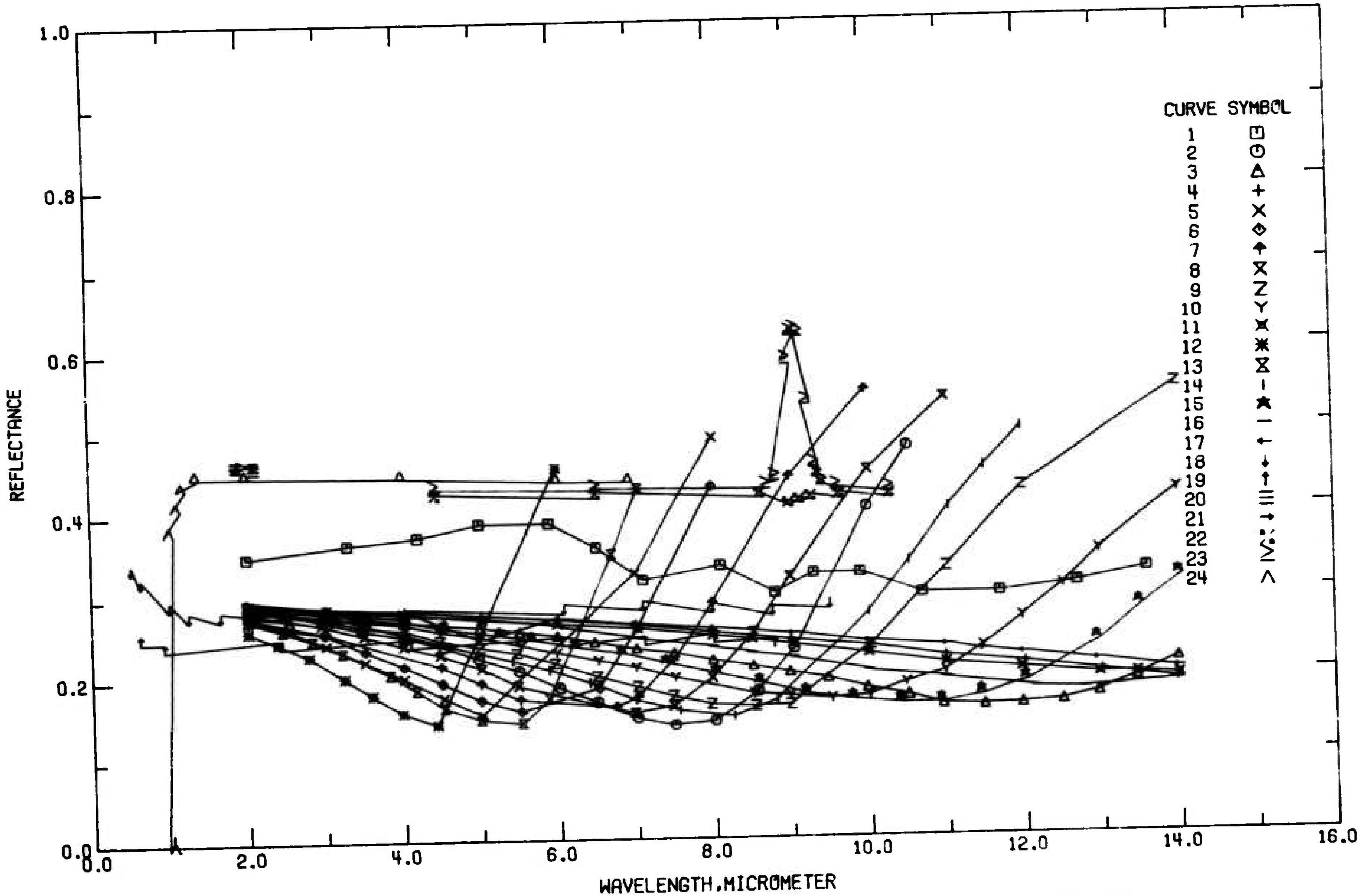


FIGURE 12-7. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON OF VARIED PURITY (WAVELENGTH DEPENDENCE).

TABLE 12-8. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF SILICON (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T30100	McCarthy, D.E.	1963	2-50	293		1 cm thick; both surfaces ground and polished to flatness of one fringe; measured with Beckman specular reflectance attachment with Beckman IR-3A in the 2-16 μm region and with Beckman IR-7 in the 12.5-50 μm region; compared to aluminum mirror; measurement temperature not stated explicitly, assumed to be 293 K; data extracted from smooth curve.
2	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-10.5	293		Doped with antimony; carrier concentration 4.47×10^{19} cm^{-3}; measured with a Perkin-Elmer Model 112 spectrometer; comparative standard a front surfaced aluminum mirror; data corrected for the reference mirror; measurement temperature not stated explicitly; assumed to be 293 K; data presented in figure; reproducibility: 0.5%.
3	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-15	293		Similar to the above specimen except doped with antimony to a carrier concentration of 1.66×10^{19} cm^{-3}.
4	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-20	293		Similar to the above specimen except doped with antimony to a carrier concentration of 0.832×10^{19} cm^{-3}.
5	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-8	293		Similar to the above specimen except doped with arsenic to a carrier concentration of 9.03×10^{19} cm^{-3}.
6	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-8	293		Similar to the above specimen except doped with arsenic to a carrier concentration of 7.92×10^{19} cm^{-3}.
7	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-10	293		Similar to the above specimen except doped with arsenic to a carrier concentration of 6.37×10^{19} cm^{-3}.
8	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-11	293		Similar to the above specimen except doped with arsenic to a carrier concentration of 5.05×10^{19} cm^{-3}.
9	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-14	293		Similar to the above specimen except doped with arsenic to a carrier concentration of 3.48×10^{19} cm^{-3}.
10	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-14	293		Similar to the above specimen except doped with arsenic to a carrier concentration of 2.84×10^{19} cm^{-3}.
11	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-14	293		Similar to the above specimen except doped with arsenic to a carrier concentration of 0.877×10^{19} cm^{-3}.
12	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-20	293		Similar to the above specimen except doped with phosphorus to a carrier concentration of 16.7×10^{19} cm^{-3}.
13	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-7	293		Similar to the above specimen except doped with phosphorus to a carrier concentration of 10.22×10^{19} cm^{-3}.
14	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-12	293		Similar to the above specimen except doped with phosphorus to a carrier concentration of 4.38×10^{19} cm^{-3}.
15	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-15	293		Similar to the above specimen except doped with phosphorus to a carrier concentration of 2.05×10^{19} cm^{-3}.
16	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-20	293		Similar to the above specimen except doped with phosphorus to a carrier concentration of 1.27×10^{19} cm^{-3}.
17	T29605	Howarth, L.E. and Gilbert, J.F.	1963	2-20	293		Similar to the above specimen except doped with phosphorus to a carrier concentration of 0.74×10^{19} cm^{-3}.

TABLE 12-8. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF SILICON (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
18	T23741	Coblentz, W.W.	1911	0.5-9.5	293	b	Specimen from Kahlbaum; quite homogeneous; polished using fine grade of emery paper covered with mixture of tin oxide and graphite; measured using fluorite prism, mirror spectrometer, and vacuum bolometer; compared with silvered glass mirror; crystal of a bluish color; data presented in figure; measurement temperature not stated explicitly, assumed to be 293 K; reported error 1-3%.
19	T23741	Coblentz, W.W.	1911	0.6-8.8	293	a	Specimen from Carborundum Co.; less homogeneous, more porous, poorer polish, harder than the above specimen; polishing and measurement techniques similar to those of the above specimen.
20	T41607	Fray, S.J., Goodwin, A.R., Johnson, F.A., and Quarrington, J.E.	1963	1.886, 2.119	293		Pure, plane parallel specimen; special apparatus measured reflectance and transmittance simultaneously; absorption negligible; optical constants calculated; precision better than 1%; each point represents separate measurement.
21	T41607	Fray, S.J., et al.	1963	1.886, 2.119	293		Calculated from known refractive index data.
22	T41640	Sato, T.	1966	4.4-10.3	293		n-type, phosphor doped single crystal; optically polished and plane parallel; source radiation split into reference and test beams; aluminized mirror of known reflectivity used as standard; incident beam chopped at 10 cycle per sec; measured under 10^{-4} mm Hg to prevent oxidation; measurement temperature not stated explicitly, assumed to be 293 K; $\theta = 4°$.
23	T41640	Sato, T.	1966	4.4-10.3	293		The above specimen measured after heating in atmosphere; oxidation shown by Reststrahlen of Si-O at 9 μm.
24	T43418	Vasil'ev, A.M., Golovner, T.M., Landsman, A.P., and Lidorenko, N.S.	1967		293		Undoped disc specimen cut from rod with free carrier concentration of 10^{14} cm^{-3}; polished on both sides; measured with IKS-14 spectrometer with reflection attachment; measurement temperature not stated explicitly; assumed to be 293 K.

TABLE 12-3. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

CURVE 1
T = 293.

λ	ρ
2.6	0.353
3.3	0.354
4.2	0.372
5.0	0.387
5.9	0.387
6.5	0.358
7.1	0.313
8.1	0.335
8.8	0.300
9.3	0.324
9.9	0.324
10.7	0.293
11.7	0.298
12.7	0.309
13.6	0.325
14.9	0.347
17.4	0.363
22.5	0.363
24.0	0.371
26.9	0.371
31.4	0.344
35.8	0.342
39.8	0.346
42.3	0.356
43.7	0.358
44.8	0.370
46.2	0.393
47.1	0.416
48.0	0.430
48.8	0.430
50.0	0.416

CURVE 2
T = 293.

λ	ρ
2.00	0.283
2.48	0.283
3.01	0.272
3.46	0.262
4.01	0.253
4.51	0.243
4.95	0.224
5.48	0.208
6.00	0.187
6.49	0.170
7.00	0.150
7.48	0.140
8.00	0.145
8.56	0.180
9.03	0.233
10.00	0.402
10.53	0.477

CURVE 3
T = 293.

λ	ρ
2.00	0.290
2.99	0.283
3.51	0.275
4.01	0.271
4.53	0.267
4.98	0.264
5.49	0.258
5.98	0.253
6.46	0.244
7.00	0.235
7.48	0.229
7.98	0.219
8.50	0.211
8.97	0.203
9.46	0.195
9.97	0.183
10.50	0.174
10.94	0.163
11.48	0.161
11.97	0.162
12.49	0.165
12.96	0.174
13.45	0.191
13.99	0.215
14.48	0.239

CURVE 4
T = 293.

λ	ρ
2.00	0.295
3.00	0.288
4.01	0.284
5.00	0.278
5.99	0.272
6.99	0.265
8.00	0.255
8.99	0.245
10.01	0.236
10.98	0.222
12.01	0.212
13.00	0.200
13.97	0.188
14.97	0.183
15.96	0.179
16.45	0.179
16.95	0.182
17.97	0.196
19.99	0.217
20.00	0.241

CURVE 5
T = 293.

λ	ρ
2.00	0.275
2.52	0.263
3.00	0.243
3.50	0.221
4.00	0.200
4.51	0.177
5.00	0.156
7.00	0.327
9.02	0.490

CURVE 6
T = 293.

λ	ρ
2.00	0.276
2.49	0.265
2.97	0.258
3.50	0.235
4.00	0.215
4.49	0.194
4.99	0.174
5.50	0.160
6.51	0.186
7.01	0.261
8.00	0.430

CURVE 7
T = 293.

λ	ρ
2.00	0.278
3.00	0.258
4.49	0.214
4.99	0.193
5.49	0.174
6.73	0.164
7.01	0.175
7.47	0.219
7.99	0.289
9.00	0.441
10.00	0.547

CURVE 8
T = 293.

λ	ρ
2.00	0.280
2.52	0.275
2.94	0.269
3.49	0.255
4.00	0.241
4.47	0.223
5.00	0.211
5.47	0.190
6.97	0.156
7.47	0.164
7.97	0.196
8.51	0.254
8.99	0.320
10.01	0.448
11.02	0.536

CURVE 9
T = 293.

λ	ρ
2.00	0.288
2.52	0.280
2.97	0.276
3.50	0.265
4.01	0.261
4.47	0.248
4.98	0.239
5.46	0.231
5.95	0.217
6.49	0.200
7.01	0.187
7.47	0.176
7.96	0.166
8.53	0.163
8.98	0.164
10.01	0.236
11.01	0.330
12.00	0.425
14.00	0.550

CURVE 10
T = 293.

λ	ρ
2.00	0.288
2.52	0.280
2.97	0.276
3.50	0.273
4.00	0.268
4.47	0.259
4.98	0.252
5.51	0.241
5.97	0.231
6.51	0.220
6.99	0.211
7.49	0.198
8.51	0.178
8.97	0.175
9.51	0.171
10.00	0.174
10.47	0.185
10.98	0.202
11.47	0.234
11.98	0.268
12.51	0.306
12.98	0.347
14.00	0.419

CURVE 11
T = 293.

λ	ρ
2.00	0.293
3.01	0.287
4.00	0.281
5.00	0.273
5.98	0.267
7.01	0.261
7.98	0.251
8.49	0.246
9.01	0.239
9.99	0.226
10.99	0.213
11.97	0.205
12.97	0.196
13.46	0.196
14.00	0.193
14.50	0.193
15.00	0.195
15.50	0.195
16.00	0.201
17.00	0.216

TABLE 12-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 11 (CONT.)	
18.00	0.235
20.00	0.233
CURVE 12 T = 293.	
2.00	0.250
2.38	0.245
2.78	0.228
3.23	0.201
3.59	0.181
3.98	0.159
4.42	0.144
6.00	0.455
CURVE 13 T = 293.	
2.00	0.274
2.44	0.262
2.82	0.249
3.21	0.233
3.82	0.235
4.16	0.186
4.52	0.165
4.99	0.150
5.52	0.145
5.87	0.175
6.70	0.350
7.05	0.428
CURVE 14 T = 293.	
2.00	0.293
2.99	0.282
3.50	0.268
4.02	0.256
4.59	0.241
5.40	0.221
CURVE 14 (CONT.)	
5.67	0.209
6.39	0.193
6.98	0.172
7.55	0.159
8.24	0.151
8.30	0.170
10.00	0.275
10.53	0.335
11.05	0.401
11.51	0.451
12.00	0.497
CURVE 15 T = 293.	
2.00	0.294
3.05	0.282
4.02	0.277
4.51	0.266
5.22	0.259
5.64	0.253
6.20	0.243
6.50	0.234
7.37	0.221
8.01	0.207
8.57	0.195
9.16	0.182
9.77	0.175
10.38	0.170
10.91	0.170
11.43	0.178
12.00	0.194
12.93	0.244
13.48	0.285
14.00	0.320
14.97	0.397
CURVE 16 T = 293.	
2.00	0.297
3.03	0.287
4.02	0.279
5.00	0.275
5.99	0.265
7.00	0.249
8.00	0.237
8.48	0.229
9.03	0.222
10.00	0.204
10.99	0.194
12.15	0.180
12.78	0.178
13.20	0.180
14.00	0.186
14.93	0.213
15.99	0.242
17.13	0.303
18.00	0.333
19.62	0.410
CURVE 17 T = 293.	
2.00	0.297
3.03	0.287
4.02	0.282
5.01	0.250
6.00	0.273
6.99	0.266
8.00	0.260
9.02	0.253
10.00	0.242
11.00	0.236
11.49	0.229
12.00	0.224
12.36	0.214
14.00	0.202
14.94	0.197
CURVE 17 (CONT.)	
15.72	0.195
16.15	0.195
16.74	0.197
17.49	0.202
18.00	0.207
18.47	0.212
18.94	0.222
20.00	0.238
CURVE 18 T = 293.	
0.51	0.339
0.63	0.321
0.99	0.293
1.24	0.280
1.65	0.280
2.42	0.283
4.01	0.281
6.07	0.284
7.09	0.287
7.99	0.283
8.76	0.279
9.50	0.286
CURVE 19 T = 293.	
0.61	0.254
0.92	0.243
2.41	0.245
4.09	0.245
6.03	0.245
7.11	0.245
8.00	0.247
8.78	0.240
CURVE 20 T = 293.	
1.886	0.4605
1.886	0.4619
2.119	0.4622
2.119	0.4581
CURVE 21 T = 293.	
1.886	0.4674
2.119	0.4654
CURVE 22 T = 293.	
4.43	0.422
6.50	0.422
8.62	0.421
8.99	0.408
9.13	0.412
9.28	0.416
9.64	0.418
10.29	0.418
CURVE 23 T = 293.	
4.43	0.430
6.50	0.429
8.70	0.429
8.83	0.439
8.99	0.583
9.04	0.615
9.09	0.619
9.16	0.614
9.24	0.532
9.33	0.455
9.37	0.442
9.43	0.432
9.61	0.427
CURVE 23 (CONT.)	
10.29	0.423
CURVE 24 T = 293.	
1.00	0.0
1.00	0.384
1.10	0.413
1.17	0.438
1.36	0.452
2.00	0.452
4.00	0.450
6.00	0.443
6.93	0.442

d. Normal Spectral Absorptance (Wavelength Dependence)

No experimental data for the normal spectral absorptance of silicon have been reported as such. However, Kirchhoff's law, stating that the absorptance of a specimen is equal to its emittance, is valid for normal spectral properties. Consequently, the values recommended for the normal spectral emittance of silicon in Section 4.12.a are repeated in Table 12-10 and Figure 12-8. The 330 K recommended values apply to a 2 mm thick, n-type single crystal of relatively high purity and resistivity. The 1075 K recommended values are applicable to relatively pure, high resistivity, single crystal silicon of any thickness. The uncertainties of the tabulated values were discussed in Section 4.12.a.

TABLE 12-10. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF HIGH RESISTIVITY SILICON (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α)

λ	α	λ	α	λ	α	λ	α
SINGLE CRYSTAL 2.0 MM THICK T = 330		SINGLE CRYSTAL 2.0 MM THICK T = 330 (CONT.)		SINGLE CRYSTAL 2.0 MM THICK T = 330 (CONT.)		SINGLE CRYSTAL OPAQUE T = 1075	
1.00	0.665	8.20	0.104	12.10	0.390	1.00	0.664
1.10	0.575	8.30	0.114	12.20	0.410	1.50	0.687
1.20	0.229B†	8.40	0.146	12.30	0.397	2.00	0.703
1.30	0.024B	8.50	0.179B†	12.40	0.389	2.50	0.712
1.40	0.017B	8.60	0.220B	12.50	0.391	3.00	0.714
1.50	0.014B	8.70	0.280B	12.60	0.403	3.80	0.714
1.60	0.013B	8.80	0.366B	12.70	0.417	4.00	0.714
1.70	0.012A	8.90	0.435B	12.80	0.427	4.50	0.715
1.80	0.011A	9.00	0.472B	12.90	0.433	5.00	0.716
1.90	0.011A	9.10	0.470B	13.00	0.439	6.00	0.716
2.00	0.010A	9.20	0.420B	13.10	0.443	7.00	0.716
2.20	0.010A	9.30	0.320B	13.20	0.451	8.00	0.716
2.40	0.009A	9.40	0.188B	13.30	0.460	9.00	0.716
2.60	0.009A	9.50	0.155	13.40	0.470	10.00	0.716
2.80	0.009A	9.60	0.158	13.50	0.482	10.60	0.716
3.00	0.009A	9.70	0.169	13.60	0.478	11.00	0.716
3.80	0.009A	9.80	0.190	13.70	0.446	12.00	0.716
4.00	0.009A	9.90	0.210	13.80	0.414	13.00	0.713
5.00	0.010A	10.00	0.234	13.90	0.367	14.00	0.712
5.50	0.013A	10.10	0.260	14.00	0.310	15.00	0.710
5.85	0.024	10.20	0.284				
6.00	0.022	10.30	0.305				
6.20	0.021	10.40	0.309				
6.40	0.023	10.50	0.306				
6.60	0.038	10.60	0.308				
6.80	0.083	10.70	0.329				
6.90	0.105	10.80	0.350				
7.00	0.112	10.90	0.373				
7.10	0.104	11.00	0.394				
7.20	0.100	11.10	0.410				
7.30	0.100	11.20	0.417				
7.40	0.104	11.30	0.417				
7.50	0.116	11.40	0.409				
7.60	0.125	11.50	0.392				
7.70	0.130	11.60	0.375				
7.80	0.122	11.70	0.358				
7.90	0.113	11.80	0.350				
8.00	0.103	11.90	0.350				
8.10	0.100	12.00	0.368				

† VALUE FOLLOWED BY AN "A" IS PROVISIONAL AND BY A "B" IS TYPICAL.

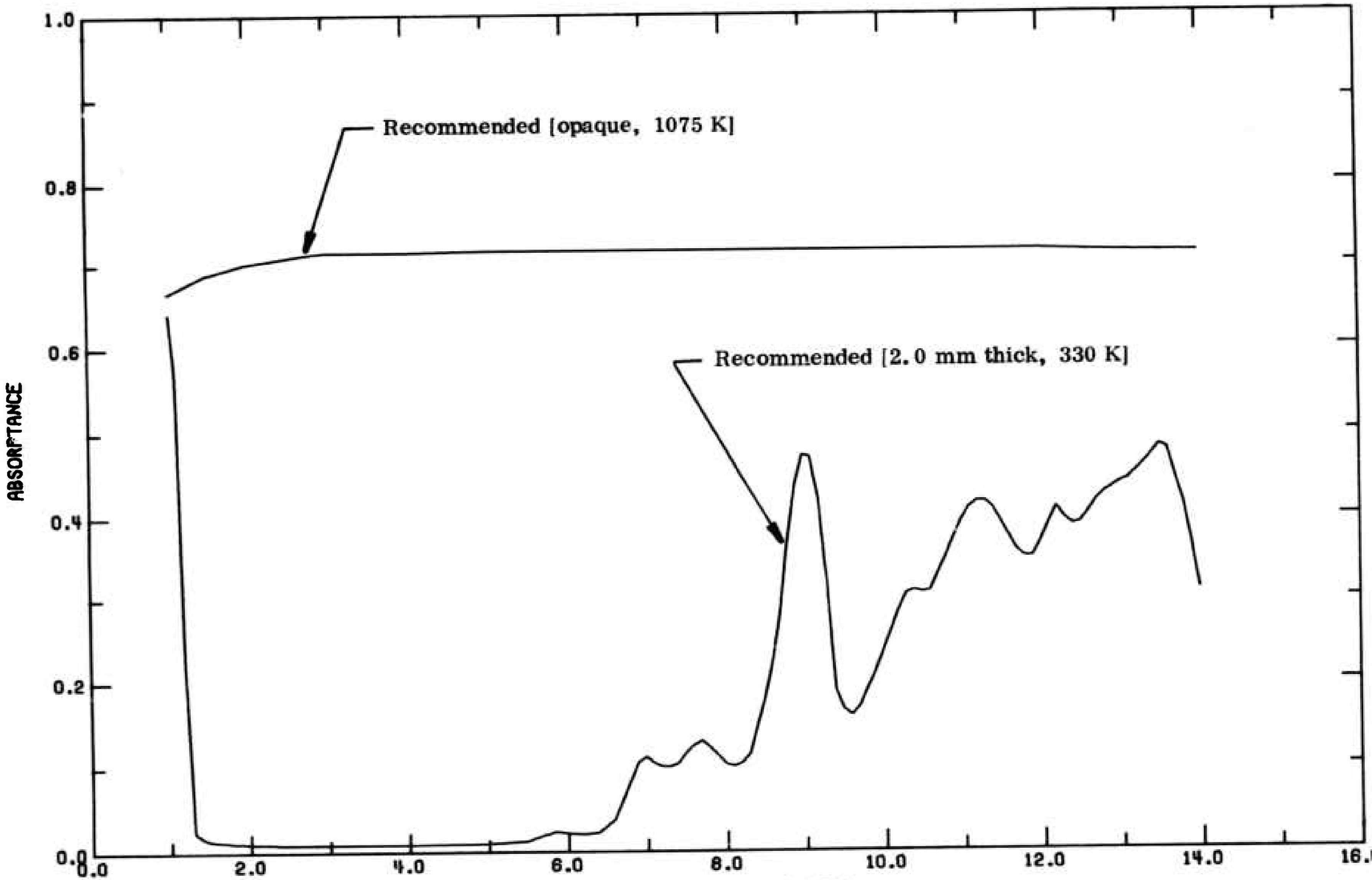


FIGURE 12-8. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF HIGH-RESISTIVITY SILICON (WAVELENGTH DEPENDENCE)

e. Normal Spectral Absorptance (Temperature Dependence)

No experimental data for the temperature dependence of the normal spectral absorptance of silicon have been reported as such. However Kirchhoff's law, stating that the absorptance of a specimen is equal to its emittance, is valid for normal spectral properties. Consequently, the values recommended for the normal spectral emittance of silicon in Section 4.12.b are repeated in Table 12-11 and Figure 12-9. As discussed in Section 4.12.b, the tabulated values are applicable only to samples about 2 mm thick, at the lower temperatures. Above about 800 K, however, the values are applicable to polished, high resistivity, single crystals of any thickness because of silicon's high temperature opacity. The values above 1100 K are extrapolated. The uncertainties of the tabulated values were discussed in Section 4.12.b.

TABLE 12-11. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF HIGH RESISTIVITY SILICON (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

T	α	T	α	T	α	T	α
SINGLE CRYSTAL 2 MM THICK λ = 2.8		SINGLE CRYSTAL 2 MM THICK λ = 3.8		SINGLE CRYSTAL 2 MM THICK λ = 5.0		SINGLE CRYSTAL 2 MM THICK λ = 10.6	
300.	0.028B†	300.	0.012B†	300.	0.011B†	300.	0.265
350.	0.032B	350.	0.017B	350.	0.015B	325.	0.280
400.	0.037B	400.	0.021B	400.	0.019B	350.	0.296
425.	0.039B	425.	0.023B	425.	0.021B	375.	0.313
450.	0.041B	450.	0.025B	450.	0.024B	400.	0.330
475.	0.042B	475.	0.028B	475.	0.027B	425.	0.346
500.	0.045B	500.	0.036B	500.	0.037B	450.	0.364
520.	0.049B	520.	0.045B	520.	0.049B	475.	0.382
540.	0.056B	540.	0.059B	540.	0.065B	500.	0.400
560.	0.069A	560.	0.074A	560.	0.085A	525.	0.419
580.	0.087A	580.	0.092A	580.	0.109A	550.	0.440
600.	0.106A	600.	0.114A	600.	0.138A	575.	0.464
620.	0.126	620.	0.138	620.	0.173	600.	0.490
640.	0.151	640.	0.169	640.	0.217	620.	0.513
660.	0.181	660.	0.206	660.	0.273	640.	0.538
680.	0.213	680.	0.253	680.	0.333	660.	0.568
700.	0.262	700.	0.314	700.	0.404	680.	0.609
720.	0.344	720.	0.393	720.	0.490	690.	0.630
740.	0.431	740.	0.487	740.	0.581	700.	0.652
760.	0.499	760.	0.560	760.	0.634	710.	0.672
780.	0.559	780.	0.610	780.	0.664	720.	0.689
800.	0.608	800.	0.649	800.	0.685	730.	0.700
820.	0.647	820.	0.678	820.	0.699	740.	0.710
840.	0.682	840.	0.698	840.	0.709	750.	0.714
860.	0.705	860.	0.711	860.	0.715	800.	0.716
880.	0.712	880.	0.714	880.	0.716	850.	0.716
900.	0.712	900.	0.714	900.	0.716	900.	0.716
950.	0.712	950.	0.714	950.	0.716	950.	0.716
1000.	0.712	1000.	0.714	1000.	0.716	1000.	0.716
1050.	0.712	1050.	0.714	1050.	0.716	1050.	0.716
1075.	0.712	1075.	0.714	1075.	0.716	1075.	0.716
1400.	0.712A	1400.	0.714A	1400.	0.716A	1400.	0.716A
1600.	0.712A	1600.	0.714A	1600.	0.716A	1600.	0.716A

† VALUE FOLLOWED BY AN "A" IS PROVISIONAL AND BY A "B" IS TYPICAL.

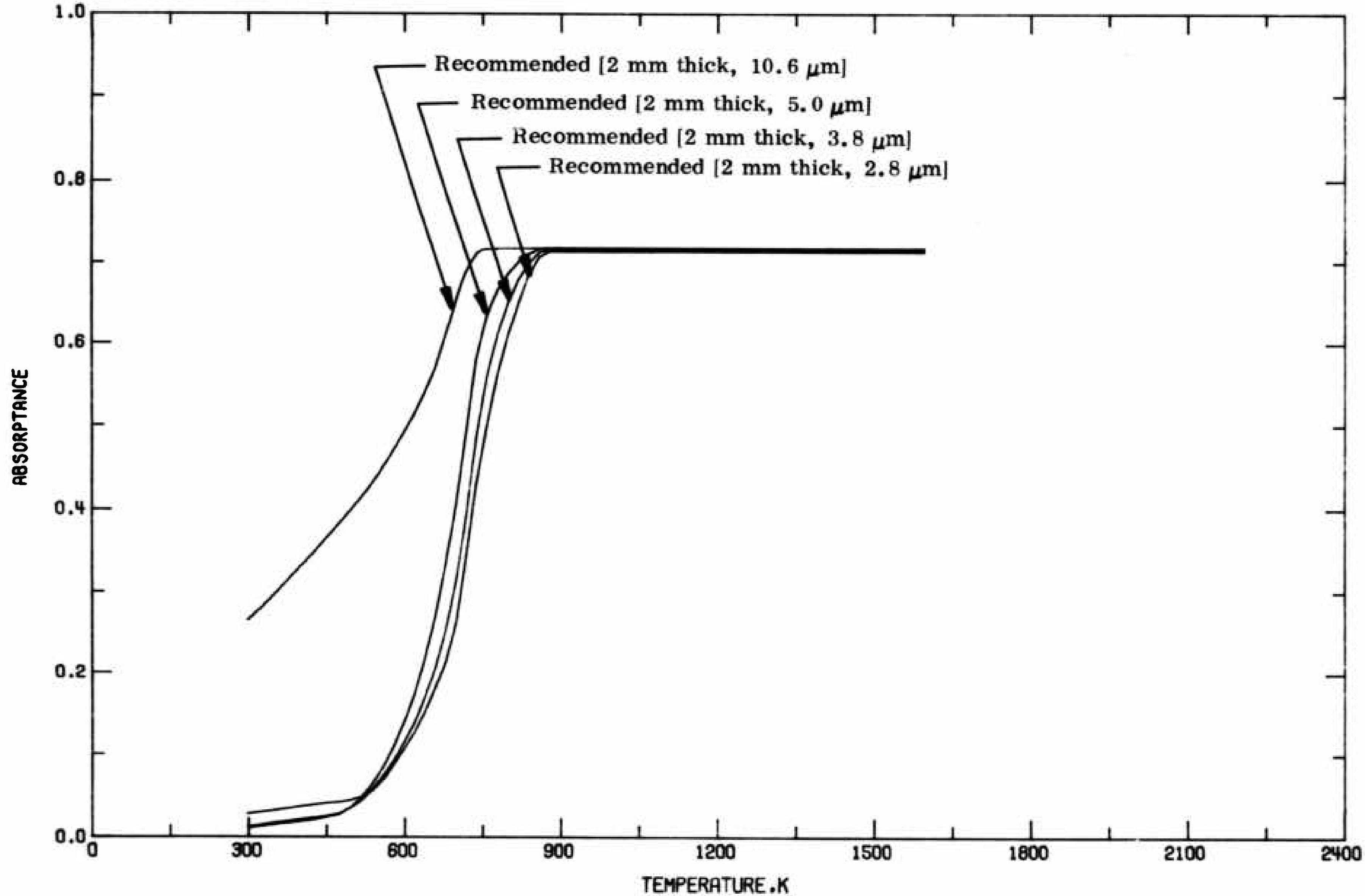


FIGURE 12-9. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF HIGH-RESISTIVITY SILICON (TEMPERATURE DEPENDENCE)

f. Normal Spectral Transmittance (Wavelength Dependence)

Thirty-one experimental data sets for the wavelength dependence of the normal spectral transmittance of silicon covering the temperature range 20-673 K are shown in Table 12-14 and Figure 12-11. Of the 31 data sets, 27 sets are for specimens of relatively high purity.

The recommended values for 330 K shown in Table 12-12 and Figure 12-10 were calculated from the recommended values for the normal spectral emittance at 330 K by use of the McMahon [T20468] relations (Eq. 2.6-10 to 2.6-12). Equation 2.6-12 for the normal spectral emittance, ϵ, can be rearranged to yield

$$ad = \ln\left(\frac{1 - R - R\epsilon}{1 - \epsilon - R}\right) \tag{4.12-1}$$

where a is the absorption coefficient, d is the thickness, and R is the single surface reflectance of a plane-parallel specimen. As discussed in previous sections, the single surface reflectance of silicon is 0.30 in the 2-15 μm range. Using this value, and the recommended emittance values, the product ad was calculated from Eq. 4.12-1 and used in the McMahon relation (Eq. 2.6-10) to determine the normal spectral transmittance. The recommended values are applicable to a 2 mm thick, silicon single crystal of relatively high purity and resistivity.

In the 1.5-6.5 μm wavelength range, the normal spectral emittance of a 2 mm thick sample is quite low, and the normal spectral transmittance approaches the 0.54 value predicted by the McMahon relations for negligible absorption and emission and a single surface reflectance of 0.30. It is worthwhile to note that the 0.54 value is accurate to within 15% for any specimen whose emittance is 0.13 or less. According to measurements by Stierwalt [T32537] (curves 8, 9 of Section 4.12.a), this criteria is satisfied in the 2-6.5 μm range by specimens as thick as 13 mm, so the recommended values are applicable to a rather wide range of thicknesses in the 2-6.5 μm range. In the 1.5-6.5 μm range, the recommended values agree to within $\pm$ 5% with the data of Labaw, et al. [T27345] (curve 7) for a 6.4 mm thick specimen; Cox, et al. [T46843] (curve 9) for a 1.5 mm specimen; Kraushaar [T10703] (curve 11) for a 4.16 mm specimen; Fray, et al. [T41607] (curves 15, 16); Sherman and Coleman [T64446] (curve 28); and Vasilev, et al. [T49418] (curve 30). They agree to within $\pm$ 10% with the data of Gillespie, et al. [T20810] (curves 2, 3) for a 2.79 mm thick specimen; Kraushaar [T10703] (curve 10) for a 0.66 mm specimen; DeWaardand Weiner [T36371] (curve 19) for an 11 mm specimen; Meyer [E58966] (curve 29); and Beam, et al. [T28949] (curve 31). The uncertainty of the 330 K recommended values is believed to be within $\pm$ 10% in the 1.5-6.5 μm wavelength range.

In the 6.5-15 μm range, absorption is no longer negligible, and the transmittance depends more strongly on the thickness of the specimen. In this region, the data of Gillespie, et al. [T20810] (curve 2) for a 2.79 mm thick specimen agrees with the recommended values to within ± 10%, as does the data of Salzberg and Villa [E3900] (curve 32). The uncertainties of the 330 K recommended values should be within ± 15% in the 6.5-15 μm range. As mentioned previously, the values reported in the 9 μm region should be considered typical only because of large differences in the amount of oxygen occluded in the process of growing single crystals by different techniques.

TABLE 12-12. RECOMMENDED NORMAL SPECTRAL TRANSMITTANCE OF HIGH RESISTIVITY SILICON (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ
SINGLE CRYSTAL 2.0 MM THICK T = 330		SINGLE CRYSTAL 2.0 MM THICK T = 330 (CONT.)		SINGLE CRYSTAL 2.0 MM THICK T = 330 (CONT.)	
1.00	0.008†	8.20	0.470	12.10	0.267
1.10	0.305B	8.30	0.464	12.20	0.252
1.20	0.334B	8.40	0.442	12.30	0.262
1.30	0.523	8.50	0.420	12.40	0.268
1.40	0.527	8.60	0.391B†	12.50	0.267
1.50	0.529	8.70	0.349B	12.60	0.257
1.60	0.530	8.80	0.286B	12.70	0.247
1.70	0.531	8.90	0.233B	12.80	0.239
1.80	0.531	9.00	0.203B	12.90	0.234
1.90	0.531	9.10	0.205B	13.00	0.229
2.00	0.532	9.20	0.244B	13.10	0.226
2.20	0.532	9.30	0.320B	13.20	0.220
2.40	0.533	9.40	0.413B	13.30	0.213
2.60	0.533	9.50	0.429	13.40	0.205
2.80	0.533	9.60	0.434	13.50	0.195
3.00	0.533	9.70	0.426	13.60	0.198
3.80	0.533	9.80	0.412	13.70	0.224
4.00	0.533	9.90	0.398	13.80	0.249
5.00	0.532	10.00	0.381	13.90	0.285
5.50	0.530	10.10	0.363	14.00	0.327
5.85	0.523	10.20	0.346		
6.00	0.524	10.30	0.331		
6.20	0.525	10.40	0.328		
6.40	0.523	10.50	0.330		
6.60	0.514	10.60	0.328		
6.80	0.484	10.70	0.313		
6.90	0.470	10.80	0.298		
7.00	0.465	10.90	0.280		
7.10	0.470	11.00	0.264		
7.20	0.473	11.10	0.252		
7.30	0.473	11.20	0.247		
7.40	0.470	11.30	0.247		
7.50	0.462	11.40	0.253		
7.60	0.456	11.50	0.266		
7.70	0.453	11.60	0.279		
7.80	0.458	11.70	0.292		
7.90	0.464	11.80	0.298		
8.00	0.471	11.90	0.298		
8.10	0.473	12.00	0.284		

† VALUE FOLLOWED BY A "B" IS TYPICAL.

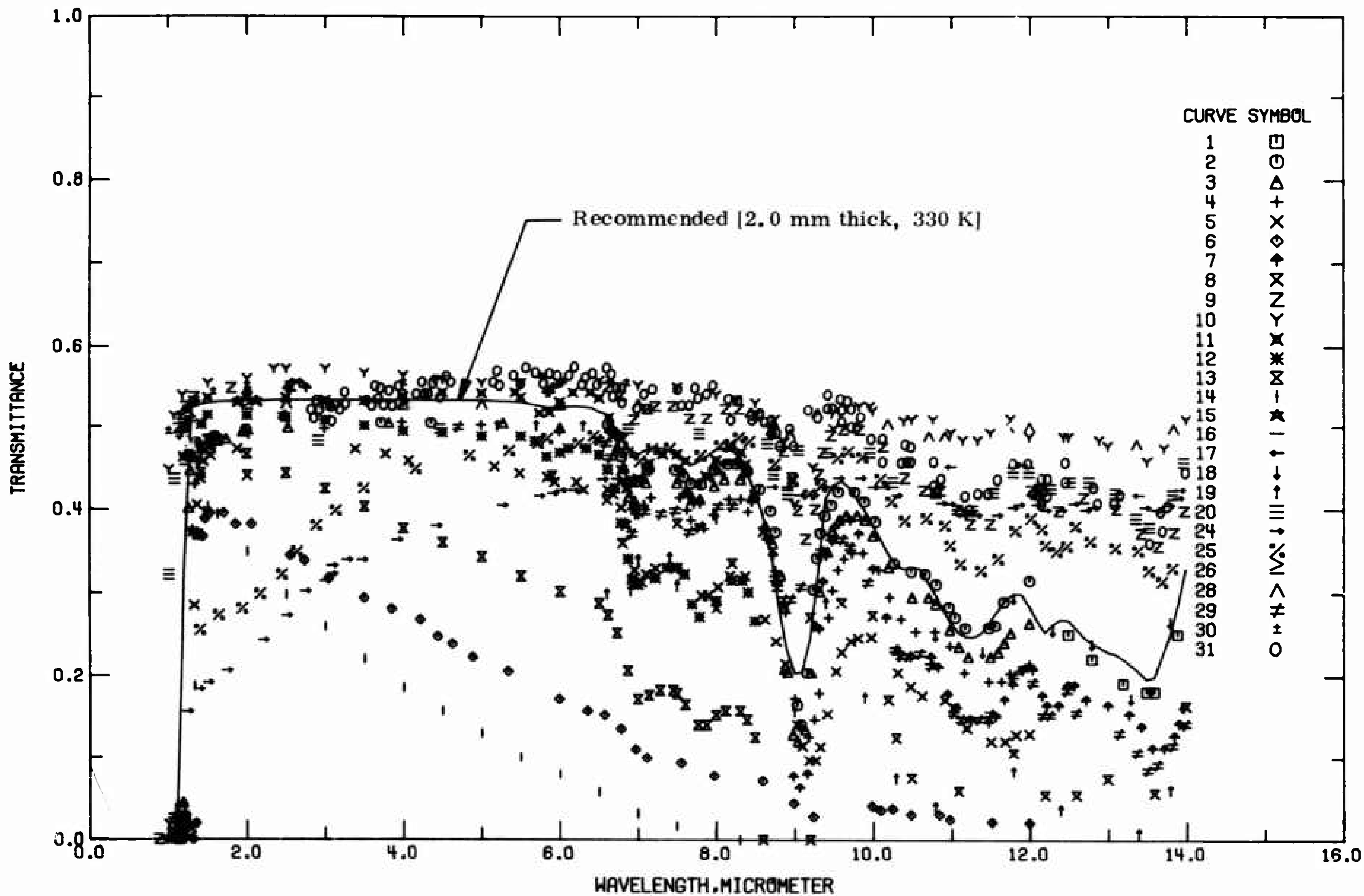


FIGURE 12-10. RECOMMENDED NORMAL SPECTRAL TRANSMITTANCE OF HIGH-RESISTIVITY SILICON (WAVELENGTH DEPENDENCE)

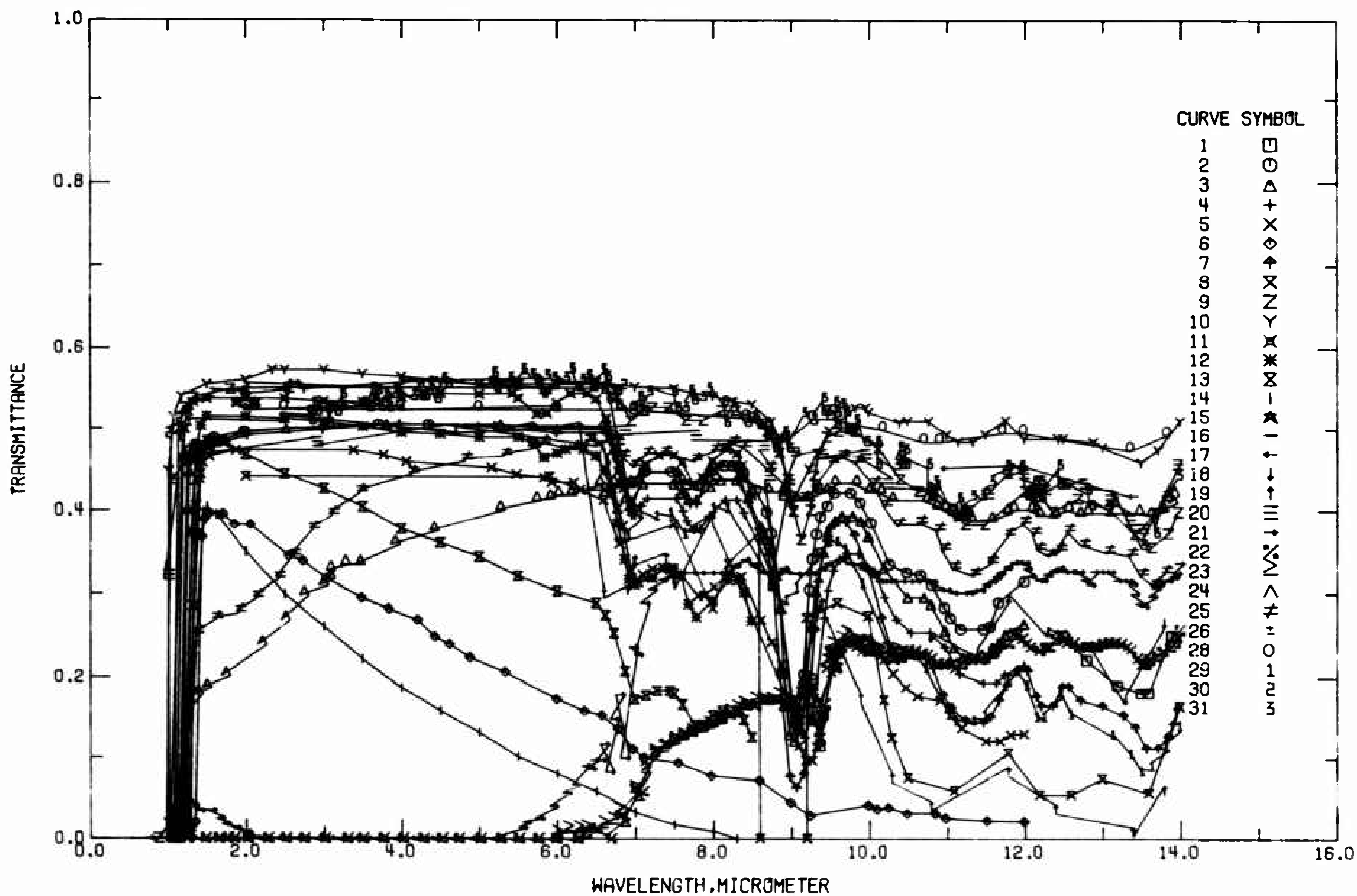


FIGURE 12-11. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON OF VARIED PURITY (WAVELENGTH DEPENDENCE).

TABLE 12-13. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF SILICON (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T33154	Lord, R.C.	1952	12-40	293		2 mm thick; optically polished; uncorrected for reflection losses; measurement temperature not stated explicitly; assumed to be 293 K.
2	T20810	Gillespie, D.T., Olsen, A.L., and Nichols, L.W.	1964	1-12	298		N-type single crystal; 6 ppb boron and 20 ppb phosphorous; resistivity 5 ohm-cm; disk 1.240 in. diameter by 0.110 in. thick; parallelism tolerance of ±2.5 μm, polished faces with flatness tolerance of ±0.0001 in.; provided by Knapic Electro-Physics, Inc.; measured using Perkin-Elmer Model 21 spectrophotometer; not corrected for reflection losses; data extracted from smoothed curve.
3	T20810	Gillespie, D.T., et al.	1964	1-12	373		The above specimen measured at 100 C; edge of sample disk about 1 C hotter than the center.
4	T20810	Gillespie, D.T., et al.	1964	1-12	473		The above specimen measured at 200 C.
5	T20810	Gillespie, D.T., et al.	1964	1.3-12	573		The above specimen measured at 300 C.
6	T20810	Gillespie, D.T., et al.	1964	1.3-12	673		The above specimen measured at 400 C; edge of sample disk about 6 C hotter than the center.
7	T27345	Labaw, K.B., Olsen, A.L., and Nichols, L.W.	1963	2-15	293		Single crystal; approx. 6 ppb boron and 20 ppb phosphorous; disk about 0.25 in. thick and 1 in. diameter; crystal supplied by Knapic Electro-Physics, Inc. and prepared by John H. Ransom Laboratories; faces polished optically flat within 5 green mercury fringes; plane parallel, with wedge angle of 0.00028 radians; measurement temperature not stated explicitly, assumed to be 293 K; data presented in figure.
8	T30100	McCarthy, D.E.	1963	2-50	293		1 cm thick; both surfaces ground and polished to flatness of one fringe; measured with Beckman IR-5A in 2-16 μm range; measurement temperature not stated explicitly, assumed to be 293 K; data extracted from smooth curve.
9	T46843	Cox, J.T., Hass, G., and Jacobus, G.F.	1961	1-14	293		High purity plate of 1.5 mm thickness; measured at room temperature; data extracted from smooth curve.
10	T10703	Kraushaar, R.	1958	1-15	293		Single crystal; 0.66 mm thick; data extracted from smooth curve; measurement temperature not stated explicitly, assumed to be 293 K.
11	T10703	Kraushaar, R.	1958	1-8.5	298		Single crystal silicon; 4.16 mm thick; data extracted from smooth curve.
12	T10703	Kraushaar, R.	1958	1-8.5	573		The above specimen measured at 300 C.
13	T10703	Kraushaar, R.	1958	1-8.5	623		The above specimen measured at 350 C.
14	T10703	Kraushaar, R.	1958	1-8.3	673		The above specimen measured at 400 C.
15	T41607	Fray, S.J., Goodwin, A.R., Johnson, F.A., and Quarrington, J.E.	1963	1.886, 2.119	293		Pure, plane parallel specimen; special apparatus measured reflectance and transmittance simultaneously; absorption negligible; $\tau + \rho \approx 0.99$; optical constants calculated; precision better than 1%; each point represents separate measurement.
16	T41607	Fray, S.J., et al.	1963	1.886, 2.119	293		Values calculated from known refractive index data.
17	T36371	DeWaard, R. and Weiner, S.	1967	5-35	293		Uncoated, high purity; 1 mm thick.
18	T36371	DeWaard, R. and Weiner, S.	1967	5-35	293		Uncoated, high purity; 5 mm thick.

TABLE 12-13. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF SILICON (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
19	T36371	DeWaard, R. and Weiner, S.	1967	5-35	293		Uncoated, high purity; 11 mm thick.
20	T35846	Linsteadt, G. F.	1965	1-15	50		1.02 mm thick and 1.27 cm in diameter; Perkin-Elmer Model 221 spectrophotometer with NaCl optics used; measurement temperature is approximate.
21	T71403	Morgan, H.T.	1972	1-14	20	Sample L-1	Be doped, p-type, single crystal specimen from Langley Research Center, NASA; resistivity 0.46 Ω cm; 0.5 to 4 mm thick and 2.2 to 2.6 cm in diameter; plane-parallel and polished to mirror finish using yellow rouge compound; measured with dual beam Perkin-Elmer Model 13 spectrometer; measurement temperature approximate.
22	T71403	Morgan, H.T.	1972	1.2-14.2	20	Sample 858-33-2	Similar to the above specimen but with a resistivity of 0.35 Ω-cm.
23	T71403	Morgan, H.T.	1972	1.2-14.2	20	Sample 858-22	Similar to the above specimen but with a resistivity of 0.40 Ω-cm.
24	T71403	Morgan, H.T.	1972	1-15	290	Sample HT-1	Single crystal, slightly p-type; resistivity 10,000 Ω-cm; 0.5 to 4 mm thick and 2.2 to 2.6 cm in diameter; boule produced by float zone technique obtained from Monsanto Co.; plane parallel and polished to mirror finish with yellow rouge compound; measured with dual beam Perkin-Elmer Model 13 spectrometer; measurement temperature approximate.
25	T71403	Morgan, H.T.	1972	2-32	290	Sample M-500-P-7	Similar to the above specimen but p-type with a resistivity of 500 Ω-cm.
26	T23974	Cox, J.T.	1961	2-6	293		Uncoated silicon plate.
27	T23974	Cox, J.T.	1961	2-6	293		Silicon plate vacuum coated with MgF_2 + ZnS on both sides with the ZnS layer on the outside.
28	T64446	Sherman, G.H. and Coleman, P.D.	1971	2.5-50	293		Optically polished specimen 10 mil thick; resistivity 3 ohm-cm; Beckman IR-12 spectrometer in double beam mode used; measurement temperature not stated explicitly, assumed to be 293 K.
29	E58966	Meyer, M.D.	1965	1-14	293		n-type, undeformed, annealed specimen; 1 ohm-cm resistivity; optically polished and plane parallel; measured in air at room temperature using Beckman IR-IV spectrophotometer.
30	T49418	Vasilev, A.M., Golovner, T.M., Landsman, A.P., and Lidorenko, N.S.	1967		293		Undoped, disc specimen cut from rod with free carrier concentration of 10^{14} cm^{-3}; polished on both sides; measured with an IKS-14 spectrometer; measurement temperature not stated explicitly, assumed to be 293 K.
31	T28949	Beam, K.E., Fahrig, R.H., Medcalf, W.E., Powderly, J.E., and Roderique, J.S.	1962	2.5-15	293		Uncoated silicon; measurement temperature not stated explicitly, assumed to be 293 K.

TABLE 12-14. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 1	
T = 293.	
12.5	0.25
12.8	0.22
13.2	0.19
13.5	0.18
13.6	0.19
13.9	0.25
14.3	0.36
14.7	0.32
15.2	0.30
15.6	0.27
16.1	0.05
16.4	0.03
16.7	0.05
17.2	0.18
17.9	0.17
18.5	0.20
19.2	0.20
19.4	0.14
20.0	0.25
20.8	0.28
21.7	0.37
22.7	0.36
23.8	0.36
25.0	0.36
26.3	0.37
27.8	0.37
29.4	0.37
31.3	0.37
33.3	0.38
34.5	0.39
35.7	0.39
37.8	0.37
38.5	0.36
CURVE 2	
T = 298.	
1.09	0.000
1.13	0.010

λ	τ
CURVE 2(CONT.)	
1.14	0.038
1.25	0.463
1.28	0.472
1.35	0.479
1.59	0.487
1.98	0.495
3.71	0.504
4.35	0.504
6.61	0.502
6.69	0.492
6.78	0.463
6.90	0.433
6.96	0.433
7.12	0.447
7.47	0.447
7.58	0.439
7.67	0.431
7.80	0.430
7.97	0.447
8.14	0.454
8.25	0.454
8.39	0.446
8.55	0.424
8.69	0.398
8.75	0.372
9.03	0.165
9.08	0.141
9.16	0.203
9.24	0.304
9.28	0.341
9.33	0.371
9.38	0.392
9.47	0.405
9.56	0.421
9.77	0.421
9.89	0.409
10.03	0.385
10.27	0.335
10.49	0.325
10.67	0.322

λ	τ
CURVE 2(CONT.)	
10.81	0.310
10.97	0.283
11.05	0.271
11.18	0.258
11.48	0.258
11.56	0.261
11.67	0.289
12.00	0.314
CURVE 3	
T = 373.	
1.12	0.000
1.16	0.011
1.19	0.044
1.25	0.401
1.27	0.446
1.31	0.462
1.42	0.472
1.52	0.484
1.73	0.484
1.94	0.493
2.52	0.498
3.81	0.504
5.27	0.504
6.00	0.498
6.64	0.498
6.73	0.474
6.81	0.450
6.85	0.434
6.88	0.415
6.95	0.410
7.10	0.432
7.49	0.432
7.60	0.421
7.69	0.412
7.79	0.412
7.97	0.428
8.10	0.436
8.30	0.436

λ	τ
CURVE 3(CONT.)	
8.45	0.414
8.62	0.380
8.72	0.359
8.82	0.321
8.87	0.283
8.91	0.205
8.98	0.129
9.04	0.121
9.13	0.135
9.21	0.204
9.27	0.261
9.32	0.302
9.42	0.349
9.48	0.374
9.57	0.387
9.66	0.393
9.80	0.393
9.90	0.387
10.00	0.368
10.20	0.330
10.50	0.295
10.71	0.295
10.80	0.287
10.98	0.256
11.10	0.235
11.22	0.223
11.50	0.223
11.60	0.229
11.68	0.240
11.76	0.252
12.00	0.264
CURVE 4	
T = 473.	
1.20	0.000
1.22	0.015
1.30	0.375
1.33	0.430
1.35	0.456

λ	τ
CURVE 4(CONT.)	
1.41	0.468
1.54	0.475
2.01	0.490
2.98	0.497
3.97	0.505
4.99	0.502
5.99	0.494
6.63	0.494
6.73	0.468
6.85	0.434
6.92	0.400
6.96	0.394
7.00	0.394
7.07	0.405
7.16	0.414
7.53	0.414
7.62	0.399
7.67	0.387
7.73	0.377
7.84	0.377
7.96	0.393
8.16	0.412
8.31	0.412
8.40	0.397
8.75	0.326
8.88	0.277
9.00	0.173
9.09	0.135
9.18	0.126
9.25	0.147
9.31	0.179
9.43	0.271
9.48	0.303
9.55	0.327
9.63	0.340
9.73	0.347
9.87	0.347
10.07	0.327
10.21	0.295
10.36	0.269

λ	τ
CURVE 4(CONT.)	
10.55	0.254
10.79	0.254
10.98	0.236
11.17	0.204
11.48	0.193
11.64	0.193
11.75	0.203
12.00	0.214
CURVE 5	
T = 573.	
1.25	0.002
1.28	0.013
1.32	0.285
1.36	0.405
1.40	0.437
1.44	0.457
1.53	0.464
1.87	0.472
3.38	0.472
3.77	0.466
4.06	0.458
5.16	0.451
5.48	0.443
5.84	0.439
5.93	0.433
6.21	0.433
6.30	0.424
6.61	0.424
6.68	0.418
6.78	0.402
6.84	0.381
6.95	0.327
7.04	0.313
7.10	0.322
7.22	0.329
7.46	0.329
7.59	0.322
7.81	0.297

TABLE 12-14. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ
CURVE	5(CONT.)
7.89	0.297
8.02	0.307
8.17	0.320
8.37	0.320
8.62	0.269
8.76	0.242
8.88	0.215
9.03	0.141
9.10	0.115
9.19	0.097
9.27	0.097
9.33	0.114
9.42	0.154
9.53	0.206
9.60	0.229
9.72	0.242
9.81	0.246
9.98	0.247
10.32	0.204
10.48	0.187
10.63	0.176
10.92	0.171
11.04	0.162
11.20	0.137
11.51	0.121
11.69	0.121
11.83	0.129
12.00	0.130
CURVE 6	
T = 673.	
1.30	0.000
1.34	0.019
1.43	0.367
1.46	0.388
1.52	0.395
1.70	0.395
1.85	0.382
2.05	0.382

λ	τ
CURVE	6(CONT.)
2.55	0.344
2.73	0.338
3.34	0.317
3.49	0.294
3.84	0.281
4.21	0.268
4.43	0.248
4.62	0.239
4.88	0.223
5.33	0.206
5.99	0.172
6.35	0.158
6.57	0.153
6.78	0.136
6.97	0.111
7.11	0.100
7.55	0.094
7.97	0.078
8.59	0.072
8.99	0.044
9.24	0.028
9.99	0.041
10.10	0.036
10.25	0.038
10.49	0.031
10.85	0.031
10.98	0.025
11.52	0.022
12.00	0.021
CURVE 7	
T = 293.	
2.00	0.542
2.52	0.547
2.58	0.554
2.67	0.554
2.75	0.548
4.39	0.559
5.76	0.562

λ	τ
CURVE	7(CONT.)
5.83	0.543
5.87	0.543
5.91	0.549
5.92	0.555
6.64	0.555
6.78	0.488
6.95	0.402
7.14	0.446
7.54	0.446
7.63	0.419
7.71	0.407
7.79	0.407
7.98	0.448
8.10	0.454
8.27	0.454
8.35	0.440
8.45	0.409
8.64	0.364
8.72	0.345
8.79	0.310
8.86	0.203
8.98	0.077
9.06	0.063
9.16	0.080
9.31	0.257
9.36	0.313
9.40	0.344
9.47	0.363
9.51	0.378
9.58	0.386
9.71	0.386
9.82	0.370
10.00	0.328
10.17	0.271
10.33	0.227
10.45	0.223
10.74	0.223
10.83	0.211
10.95	0.178
11.06	0.162

λ	τ
CURVE	7(CONT.)
11.24	0.147
11.48	0.144
11.57	0.151
11.68	0.171
11.78	0.190
11.91	0.208
12.04	0.209
12.16	0.176
12.22	0.164
12.37	0.164
12.49	0.185
12.57	0.188
12.72	0.171
13.00	0.164
13.27	0.153
13.43	0.138
13.57	0.112
13.72	0.112
13.85	0.127
13.91	0.142
13.97	0.161
14.03	0.194
14.09	0.242
14.14	0.270
14.20	0.292
14.29	0.304
14.48	0.304
14.60	0.289
14.72	0.283
15.00	0.283
CURVE 8	
T = 293.	
2.0	0.440
5.9	0.440
6.6	0.411
6.8	0.359
7.5	0.383
8.0	0.282

λ	τ
CURVE	8(CONT.)
8.2	0.335
8.6	0.373
8.6	0.000
9.2	0.000
9.2	0.271
9.6	0.288
10.0	0.273
10.2	0.171
10.3	0.125
10.5	0.075
11.1	0.059
11.8	0.106
12.2	0.054
12.6	0.054
13.0	0.074
13.6	0.056
14.0	0.163
14.5	0.182
15.3	0.156
15.7	0.073
16.4	0.038
17.1	0.057
17.7	0.057
18.3	0.079
19.0	0.057
21.2	0.138
22.6	0.181
23.7	0.207
26.0	0.230
33.9	0.230
36.5	0.209
38.9	0.188
41.0	0.166
43.7	0.132
45.1	0.102
47.3	0.087
50.0	0.063

λ	τ
CURVE 9	
T = 293.	
0.87	0.000
1.07	0.025
1.13	0.497
1.22	0.525
1.33	0.537
1.60	0.548
2.56	0.550
6.62	0.550
6.78	0.539
6.95	0.509
7.12	0.522
7.23	0.526
7.44	0.526
7.66	0.510
7.88	0.510
8.12	0.522
8.29	0.522
8.51	0.514
8.70	0.496
8.86	0.470
8.97	0.438
9.04	0.399
9.14	0.364
9.26	0.400
9.31	0.442
9.36	0.468
9.47	0.489
9.62	0.496
9.83	0.496
10.13	0.475
10.41	0.438
10.65	0.423
10.86	0.423
11.25	0.383
11.59	0.383
12.02	0.423
12.15	0.423
12.37	0.398
12.69	0.414

TABLE 12-14. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ
CURVE 9(CONT.)	
13.11	0.400
13.42	0.371
13.64	0.355
13.85	0.372
13.98	0.398
14.13	0.430
14.29	0.449
14.39	0.459
14.55	0.470
CURVE 10	
T = 293.	
1.00	0.018
1.00	0.447
1.07	0.513
1.17	0.539
1.50	0.554
2.00	0.560
2.34	0.572
2.50	0.572
3.00	0.572
3.50	0.567
4.00	0.564
4.50	0.559
5.00	0.555
5.50	0.555
6.00	0.555
6.50	0.558
7.00	0.552
7.50	0.550
8.00	0.540
8.26	0.534
8.50	0.530
8.75	0.509
8.87	0.481
9.00	0.406
9.24	0.450
9.50	0.497
9.83	0.526

λ	τ
CURVE 10(CONT.)	
9.96	0.526
10.00	0.520
10.40	0.507
10.50	0.509
10.77	0.509
11.00	0.492
11.15	0.483
11.34	0.483
11.50	0.492
11.76	0.510
12.00	0.487
12.44	0.487
12.59	0.487
12.89	0.483
13.00	0.476
13.50	0.457
13.72	0.473
14.00	0.509
14.12	0.520
14.50	0.512
14.76	0.516
15.00	0.507
CURVE 11	
T = 298.	
1.08	0.000
1.10	0.025
1.19	0.462
1.21	0.498
1.27	0.520
1.32	0.531
1.50	0.536
2.00	0.536
2.50	0.536
3.00	0.533
3.50	0.532
4.00	0.538
4.50	0.543
5.00	0.542

λ	τ
CURVE 11(CONT.)	
5.43	0.543
5.50	0.537
5.74	0.517
5.87	0.518
6.00	0.531
6.17	0.543
6.39	0.543
6.50	0.536
6.63	0.512
6.79	0.447
6.86	0.426
7.00	0.437
7.14	0.455
7.31	0.466
7.50	0.466
7.61	0.458
7.76	0.431
7.87	0.440
8.00	0.459
8.18	0.474
8.32	0.468
8.38	0.454
8.50	0.418
CURVE 12	
T = 573.	
1.14	0.000
1.19	0.028
1.31	0.372
1.36	0.476
1.42	0.502
1.50	0.514
2.00	0.513
2.50	0.511
3.00	0.507
3.50	0.501
4.00	0.494
4.50	0.492
5.00	0.488

λ	τ
CURVE 12(CONT.)	
5.50	0.488
5.63	0.482
5.83	0.463
6.00	0.468
6.11	0.473
6.34	0.473
6.50	0.465
6.61	0.448
6.70	0.426
6.78	0.384
6.87	0.340
6.92	0.316
7.00	0.310
7.22	0.318
7.37	0.330
7.50	0.330
7.59	0.322
7.69	0.287
7.79	0.272
8.00	0.291
8.29	0.315
8.33	0.315
8.41	0.301
8.50	0.267
CURVE 13	
T = 623.	
1.14	0.000
1.21	0.024
1.37	0.369
1.41	0.443
1.50	0.483
1.63	0.482
2.00	0.466
2.50	0.443
3.00	0.425
3.50	0.403
4.00	0.377
4.50	0.360

λ	τ
CURVE 13(CONT.)	
5.00	0.343
5.50	0.320
6.00	0.302
6.50	0.288
6.62	0.274
6.73	0.253
6.87	0.207
7.00	0.172
7.14	0.177
7.28	0.183
7.45	0.183
7.50	0.179
7.61	0.166
7.77	0.141
7.88	0.141
8.00	0.153
8.12	0.158
8.31	0.158
8.40	0.147
8.50	0.126
CURVE 14	
T = 673.	
1.14	0.000
1.25	0.026
1.32	0.187
1.45	0.397
1.50	0.403
1.62	0.394
2.00	0.349
2.50	0.298
3.00	0.260
3.50	0.221
4.00	0.186
4.50	0.158
5.00	0.131
5.50	0.101
6.00	0.080
6.50	0.058

λ	τ
CURVE 14(CONT.)	
7.00	0.032
7.50	0.017
8.00	0.009
8.30	0.000
CURVE 15	
T = 293.	
1.886	0.5314
1.886	0.5298
2.119	0.5310
2.119	0.5320
CURVE 16	
T = 293.	
1.886	0.5326
2.119	0.5347
CURVE 17	
T = 293.	
11.0	0.451
11.9	0.454
13.4	0.417
14.1	0.519
15.2	0.519
15.8	0.502
15.9	0.357
16.1	0.257
16.8	0.447
18.4	0.504
19.9	0.562
21.4	0.600
23.0	0.625
25.0	0.641
27.0	0.623
29.9	0.604
35.0	0.593

TABLE 12-14. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

CURVE 18
T = 293.

λ	τ
10.8	0.249
11.4	0.223
11.8	0.294
12.3	0.255
12.8	0.238
13.3	0.172
13.8	0.265
14.2	0.392
14.9	0.349
15.6	0.299
15.8	0.054
16.3	0.021
17.1	0.179
17.9	0.180
18.7	0.234
19.3	0.203
21.9	0.392
24.9	0.459
30.0	0.453
35.0	0.453

CURVE 19
T = 293.

λ	τ
5.2	0.501
5.7	0.501
6.3	0.501
6.6	0.299
6.9	0.303
7.0	0.339
7.4	0.342
7.5	0.309
8.0	0.389
9.0	0.157
9.4	0.288
9.9	0.174
10.3	0.075
10.8	0.040
11.8	0.083

CURVE 19 (CONT.)

λ	τ
12.4	0.036
13.4	0.008
13.8	0.060
14.1	0.200
14.9	0.158
15.9	0.008
17.1	0.006
18.9	0.048
19.9	0.065
22.0	0.203
23.9	0.303
24.9	0.336
25.6	0.322
29.8	0.321
33.1	0.316
35.0	0.323

CURVE 20
T = 50.

λ	τ
1.00	0.321
1.07	0.436
1.21	0.458
1.52	0.472
2.91	0.482
4.47	0.497
6.88	0.497
7.78	0.491
8.65	0.479
8.73	0.442
8.78	0.309
8.91	0.418
9.05	0.471
9.41	0.468
9.96	0.468
10.26	0.433
10.81	0.420
11.08	0.400
11.27	0.399
11.54	0.420

CURVE 20 (CONT.)

λ	τ
11.79	0.445
11.99	0.445
12.13	0.425
12.28	0.425
12.52	0.433
12.76	0.433
13.10	0.419
13.36	0.389
13.53	0.378
13.83	0.418
13.97	0.456
14.19	0.471
14.70	0.471
15.04	0.463

CURVE 21
T = 20.

λ	τ
0.75	0.000
1.01	0.000
1.08	0.018
1.13	0.046
1.26	0.044
1.33	0.040
1.41	0.033
1.56	0.034
1.67	0.024
1.74	0.017
1.89	0.012
2.01	0.007
2.13	0.000
2.26	0.000
2.39	0.000
2.53	0.000
2.64	0.000
2.76	0.000
2.91	0.000
3.08	0.000
3.38	0.000
3.55	0.000

CURVE 21 (CONT.)

λ	τ
3.74	0.000
3.92	0.000
4.12	0.000
4.28	0.000
4.36	0.000
4.65	0.000
4.89	0.000
5.24	0.000
5.56	0.013
5.61	0.019
5.78	0.024
5.96	0.039
6.12	0.056
6.25	0.066
6.37	0.090
6.44	0.086
6.48	0.097
6.57	0.097
6.61	0.117
6.68	0.082
6.74	0.148
6.81	0.178
6.87	0.099
6.98	0.236
7.05	0.226
7.13	0.288
7.23	0.304
7.36	0.315
7.49	0.320
7.60	0.324
7.74	0.324
7.85	0.324
7.99	0.324
8.08	0.324
8.21	0.324
8.30	0.333
8.42	0.340
8.53	0.334
8.63	0.325
8.74	0.323

CURVE 21 (CONT.)

λ	τ
8.85	0.324
8.92	0.330
8.96	0.325
9.08	0.323
9.19	0.323
9.28	0.323
9.32	0.324
9.41	0.329
9.49	0.335
9.65	0.341
9.77	0.335
9.88	0.335
9.94	0.330
10.02	0.327
10.09	0.321
10.15	0.314
10.20	0.314
10.26	0.314
10.32	0.314
10.43	0.314
10.53	0.314
10.62	0.314
10.73	0.315
10.83	0.314
10.93	0.304
11.01	0.304
11.10	0.300
11.23	0.300
11.30	0.300
11.36	0.303
11.45	0.303
11.52	0.310
11.60	0.314
11.66	0.319
11.71	0.324
11.80	0.331
11.88	0.337
11.94	0.337
12.02	0.337
12.05	0.330

CURVE 21 (CONT.)

λ	τ
12.10	0.321
12.20	0.315
12.25	0.315
12.31	0.322
12.39	0.327
12.47	0.331
12.52	0.326
12.60	0.326
12.64	0.326
12.72	0.326
12.78	0.316
12.86	0.310
12.90	0.326
12.98	0.326
13.05	0.326
13.12	0.326
13.20	0.315
13.27	0.315
13.35	0.315
13.40	0.311
13.43	0.299
13.48	0.288
13.55	0.284
13.66	0.296
13.70	0.306
13.75	0.311
13.85	0.315
13.93	0.319
13.97	0.324
14.00	0.336
14.04	0.345
14.12	0.352

CURVE 22
T = 20.

λ	τ
1.24	0.000
1.48	0.000
1.65	0.000
1.76	0.000

TABLE 12-14. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 22 (CONT.)		CURVE 22 (CONT.)		CURVE 22 (CONT.)		CURVE 23		CURVE 23 (CONT.)		CURVE 24 (CONT.)	
1.85	0.000	8.83	0.172	11.61	0.231	T = 20.		9.55	0.238	6.92	0.433
2.02	0.000	8.91	0.167	11.64	0.235	6.00	0.005	9.60	0.210	7.04	0.437
2.28	0.000	8.98	0.167	11.72	0.241	6.14	0.010	9.66	0.245	7.90	0.437
2.51	0.000	9.06	0.146	11.81	0.241	6.28	0.010	9.73	0.251	8.04	0.443
2.75	0.000	9.13	0.156	11.87	0.253	6.39	0.011	9.79	0.246	8.39	0.443
3.01	0.000	9.16	0.189	11.93	0.253	6.60	0.016	9.85	0.240	8.72	0.427
3.30	0.000	9.23	0.183	11.98	0.247	6.72	0.021	9.93	0.240	8.91	0.427
3.50	0.000	9.28	0.190	12.03	0.241	6.80	0.033	10.02	0.240	9.07	0.417
3.77	0.000	9.33	0.146	12.08	0.236	6.88	0.018	10.09	0.231	9.24	0.417
4.02	0.000	9.37	0.125	12.20	0.232	7.00	0.061	10.16	0.231	9.37	0.427
4.28	0.000	9.44	0.167	12.28	0.236	7.05	0.050	10.26	0.231	9.47	0.427
4.52	0.000	9.46	0.211	12.33	0.236	7.14	0.085	10.30	0.231	9.57	0.438
4.74	0.000	9.51	0.232	12.41	0.246	7.25	0.106	10.38	0.231	9.85	0.438
5.02	0.000	9.59	0.211	12.47	0.251	7.37	0.111			10.01	0.427
5.28	0.000	9.65	0.236	12.52	0.246	7.52	0.121	CURVE 24		10.16	0.427
5.51	0.000	9.72	0.242	12.55	0.242	7.62	0.126	T = 290.		10.31	0.417
5.76	0.000	9.80	0.241	12.64	0.242	7.74	0.131			10.75	0.417
5.99	0.000	9.85	0.237	12.71	0.236	7.87	0.136	1.05	0.012	10.88	0.408
6.27	0.000	9.92	0.231	12.80	0.237	7.96	0.140	1.24	0.156	10.99	0.407
6.37	0.007	10.00	0.231	12.90	0.237	8.10	0.146	1.38	0.183	11.16	0.393
6.51	0.012	10.08	0.231	12.94	0.237	8.23	0.155	1.50	0.191	11.25	0.397
6.69	0.000	10.16	0.226	13.01	0.241	8.32	0.160	1.74	0.206	11.33	0.393
6.82	0.029	10.21	0.222	13.09	0.242	8.40	0.165	2.21	0.243	11.59	0.393
7.00	0.063	10.33	0.222	13.17	0.242	8.55	0.170	2.51	0.273	11.79	0.402
7.10	0.058	10.38	0.226	13.25	0.241	8.65	0.170	2.75	0.302	11.87	0.406
7.13	0.096	10.44	0.232	13.32	0.237	8.76	0.170	3.00	0.314	12.10	0.406
7.25	0.108	10.52	0.232	13.37	0.233	8.85	0.176	3.09	0.322	12.21	0.399
7.38	0.118	10.60	0.232	13.46	0.223	8.91	0.162	3.09	0.332	12.41	0.399
7.50	0.124	10.68	0.227	13.51	0.216	8.99	0.166	3.28	0.339	12.57	0.407
7.62	0.129	10.76	0.227	13.56	0.216	9.03	0.168	3.47	0.339	12.72	0.399
7.73	0.133	10.81	0.222	13.61	0.221	9.08	0.134	3.92	0.363	12.82	0.402
7.87	0.139	10.89	0.216	13.71	0.225	9.11	0.146	4.42	0.380	13.48	0.402
8.00	0.145	10.97	0.216	13.78	0.231	9.14	0.176	5.27	0.405	13.63	0.399
8.11	0.150	11.07	0.216	13.88	0.236	9.20	0.196	5.74	0.416	13.79	0.405
8.23	0.155	11.11	0.211	13.94	0.242	9.24	0.180	5.91	0.419	13.91	0.414
8.33	0.159	11.20	0.216	13.96	0.248	9.30	0.195	6.02	0.423	13.93	0.424
8.43	0.166	11.25	0.222	14.00	0.257	9.32	0.167	6.18	0.423	14.05	0.431
8.55	0.166	11.33	0.222	14.07	0.265	9.38	0.112	6.55	0.436	14.09	0.444
8.67	0.172	11.44	0.222	14.16	0.265	9.42	0.157	6.73	0.437	14.16	0.453
8.72	0.172	11.50	0.226			9.48	0.216	6.81	0.433	14.33	0.467

TABLE 12-14. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 24(CONT.)	
14.45	0.467
14.62	0.458
14.87	0.458
14.96	0.453
15.05	0.428
15.10	0.443
CURVE 25	
T = 290.	
1.04	0.038
1.12	0.013
1.39	0.255
1.63	0.273
1.93	0.281
2.16	0.298
2.44	0.321
2.63	0.348
2.88	0.380
3.13	0.398
3.49	0.425
4.15	0.448
4.84	0.464
5.35	0.470
5.72	0.479
5.84	0.485
6.24	0.479
6.43	0.488
6.68	0.488
6.79	0.483
6.87	0.468
7.02	0.457
7.18	0.472
7.41	0.473
7.80	0.464
8.05	0.476
8.18	0.478
8.29	0.486
8.42	0.481
8.75	0.454

λ	τ
CURVE 25(CONT.)	
8.98	0.434
9.19	0.418
9.34	0.428
9.55	0.461
9.69	0.469
9.87	0.462
10.10	0.436
10.24	0.409
10.41	0.386
10.69	0.389
10.92	0.380
10.99	0.356
11.12	0.334
11.38	0.326
11.60	0.340
11.82	0.374
12.02	0.389
12.16	0.376
12.21	0.356
12.35	0.349
12.48	0.355
12.59	0.379
12.78	0.361
13.10	0.353
13.39	0.350
13.53	0.326
13.70	0.313
13.83	0.329
14.18	0.428
14.25	0.481
14.33	0.497
14.49	0.506
14.76	0.494
15.21	0.484
15.38	0.474
15.63	0.450
15.87	0.377
16.04	0.148
16.24	0.090
16.38	0.086

λ	τ
CURVE 25(CONT.)	
16.59	0.142
16.93	0.254
17.08	0.290
17.19	0.299
17.40	0.300
17.50	0.294
17.67	0.287
17.81	0.289
18.02	0.302
18.56	0.320
18.85	0.333
19.57	0.340
20.09	0.359
20.66	0.373
21.09	0.395
21.39	0.405
22.24	0.419
22.95	0.424
23.32	0.424
23.72	0.408
23.92	0.421
24.37	0.432
24.70	0.424
24.95	0.413
25.16	0.425
25.53	0.435
25.79	0.425
26.15	0.426
26.24	0.413
26.34	0.404
26.49	0.423
26.70	0.420
26.95	0.424
27.40	0.424
27.64	0.416
27.89	0.417
28.18	0.431
28.47	0.453
28.73	0.437
28.97	0.421

λ	τ
CURVE 25(CONT.)	
29.20	0.427
29.50	0.412
29.72	0.423
29.93	0.423
30.20	0.409
30.52	0.417
30.64	0.444
30.49	0.453
30.93	0.446
31.25	0.418
31.43	0.415
31.57	0.423
31.66	0.432
31.93	0.434
CURVE 26	
T = 293.	
2.00	0.524
4.00	0.524
6.00	0.524
CURVE 27	
T = 293.	
2.00	0.581
2.12	0.702
2.38	0.860
2.49	0.919
2.61	0.957
2.73	0.979
2.92	1.000
3.08	0.986
3.38	0.959
3.77	0.890
4.09	0.943
4.35	0.806
4.67	0.777
5.00	0.739
5.27	0.721

λ	τ
CURVE 27(CONT.)	
5.57	0.699
6.00	0.670
CURVE 28	
T = 293.	
2.50	0.528
3.00	0.528
4.00	0.528
5.00	0.528
6.00	0.528
7.00	0.528
8.44	0.518
8.73	0.504
8.94	0.490
9.29	0.517
9.53	0.517
10.19	0.503
10.72	0.488
10.92	0.488
11.73	0.499
12.00	0.499
13.37	0.478
13.84	0.497
14.49	0.497
15.00	0.486
15.39	0.469
15.74	0.422
16.11	0.411
16.41	0.424
16.64	0.459
17.38	0.468
19.02	0.468
20.00	0.475
21.04	0.485
23.13	0.485
25.13	0.470
26.55	0.462
31.20	0.462
33.97	0.454

λ	τ
CURVE 28(CONT.)	
40.10	0.446
45.93	0.446
49.79	0.464
CURVE 29	
T = 293.	
1.00	0.000
1.05	0.027
1.16	0.489
1.19	0.501
1.27	0.508
2.46	0.513
4.70	0.499
6.49	0.483
6.59	0.479
6.65	0.462
6.83	0.382
6.92	0.370
7.08	0.397
7.29	0.394
7.47	0.398
7.65	0.372
7.79	0.379
8.02	0.403
8.20	0.403
8.75	0.317
8.86	0.292
8.95	0.292
9.08	0.307
9.34	0.349
9.51	0.363
9.61	0.363
9.71	0.354
9.93	0.312
10.28	0.232
10.36	0.224
10.45	0.224
10.60	0.227
10.74	0.212

TABLE 12-14. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF VARIED PURITY SILICON (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 29 (CONT.)		CURVE 31 (CONT.)		CURVE 31 (CONT.)		CURVE 31 (CONT.)		CURVE 31 (CONT.)	
11.83	0.155	3.10	0.506	6.67	0.566	9.86	0.512	14.59	0.453
11.13	0.147	3.14	0.527	6.69	0.538	9.99	0.485	14.66	0.467
11.36	0.147	3.20	0.521	6.74	0.549	10.14	0.485	14.81	0.462
11.50	0.154	3.26	0.543	6.80	0.549	10.14	0.457	14.89	0.478
11.79	0.200	3.27	0.528	6.81	0.530	10.38	0.456	14.89	0.467
11.92	0.209	3.54	0.532	7.00	0.523	10.43	0.478	15.00	0.464
12.04	0.191	3.61	0.526	7.09	0.541	10.45	0.457		
12.17	0.152	3.65	0.551	7.13	0.522	10.50	0.475		
12.26	0.152	3.69	0.535	7.20	0.547	10.50	0.457		
12.48	0.152	3.72	0.548	7.52	0.547	10.79	0.457		
12.60	0.155	3.76	0.527	7.57	0.527	10.79	0.429		
13.15	0.130	3.83	0.545	7.67	0.527	10.88	0.437		
13.38	0.106	3.87	0.526	7.74	0.549	11.12	0.398		
13.51	0.084	3.95	0.551	7.78	0.536	11.19	0.416		
13.64	0.091	4.00	0.541	7.89	0.541	11.24	0.400		
13.83	0.115	4.18	0.541	7.97	0.552	11.35	0.419		
14.00	0.141	4.25	0.556	8.17	0.535	11.48	0.419		
		4.28	0.541	8.20	0.508	11.60	0.436		
CURVE 30		4.33	0.541	8.29	0.533	11.80	0.455		
T = 293.		4.39	0.554	8.47	0.508	11.99	0.455		
		4.48	0.537	8.57	0.517	12.06	0.419		
1.00	0.0	4.56	0.563	8.63	0.506	12.12	0.418		
1.00	0.493	4.62	0.556	8.72	0.508	12.16	0.437		
1.15	0.511	5.16	0.556	8.72	0.492	12.16	0.406		
1.30	0.528	5.21	0.570	8.78	0.492	12.24	0.437		
1.57	0.543	5.24	0.552	8.82	0.476	12.24	0.416		
2.00	0.551	5.42	0.564	8.95	0.497	12.47	0.456		
4.00	0.555	5.51	0.554	9.00	0.476	12.47	0.433		
6.00	0.555	5.58	0.574	9.19	0.521	12.83	0.426		
6.86	0.555	5.70	0.568	9.31	0.511	12.88	0.407		
		5.80	0.554	9.44	0.540	13.09	0.407		
CURVE 31		5.88	0.567	9.44	0.523	13.17	0.417		
T = 293.		5.98	0.564	9.50	0.523	13.55	0.359		
		6.13	0.564	9.60	0.535	13.69	0.397		
2.49	0.512	6.20	0.575	9.62	0.506	13.71	0.374		
2.83	0.521	6.30	0.553	9.62	0.521	13.77	0.403		
2.87	0.510	6.34	0.562	9.69	0.532	14.00	0.444		
2.90	0.532	6.43	0.567	9.74	0.522	14.15	0.484		
2.94	0.521	6.49	0.553	9.74	0.499	14.30	0.488		
3.08	0.525	6.61	0.574	9.81	0.499	14.57	0.469		

g. Normal Spectral Transmittance (Temperature Dependence)

The available experimental data for the temperature dependence of the normal spectral transmittance of silicon are shown in Table 12-17 and Figure 12-13. Only Gillespie, et al. [T20810] (curves 1-4) and Kraushaar [T10703] (curves 5-7) have reported the normal spectral transmittance above room temperature. The data of these curves were obtained by reading points from the spectral curves of Section 12.4.f at selected wavelengths of 2.8, 3.8, 5.0, and 10.6 μm.

In the 300-700 K temperature range, the recommended values shown in Table 12-15 and Figure 12-12 were calculated from the recommended values for the normal spectral emittance given in Section 4.12.b by use of Eq. 4.12-1 and the McMahon relation (Eq. 2.6-10), in a manner similar to that described in the preceding section. Refractive index and absorption coefficient measurements indicate that the single surface reflectance does not vary greatly with temperature, and the room temperature value of 0.30 was assumed to hold at higher temperatures. The recommended values are subject to the same restrictions as discussed in Section 4.12.b; they apply only to polished, plane-parallel, relatively pure single crystals which are about 2 mm thick.

Both the experimental data and the calculations from emittance data show that the transmittance of relatively pure silicon drops rapidly toward zero above about 600 K, for the wavelengths of interest. Above about 800 K, the 2 mm thick specimens are completely opaque. This rapid drop in transmittance with increasing temperature is the result of the thermal excitation of electrons to the conduction band, with consequent absorption due to free carriers. The experimental data exhibit a sharper drop to zero transmittance than do the calculations from emittance recommendations. The more rapid drop of the experimental data was followed in generating recommended values in the 600-800 K range.

In the 300-600 K temperature range, the uncertainty of the recommended values is believed to lie within $\pm$15%. At greater temperatures, the high slope of the curves as the transmittance drops rapidly to zero results in larger uncertainties.

Above 600 K, the general trend of the transmittance to zero can be accepted without reservation, but the tabulated values should be considered typical only.

TABLE 12-15. RECOMMENDED NORMAL SPECTRAL TRANSMITTANCE OF HIGH RESISTIVITY SILICON (TEMPERATURE DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

T	τ	T	τ	T	τ	T	τ
SINGLE CRYSTAL 2 MM THICK λ = 10.6		SINGLE CRYSTAL 2 MM THICK λ = 5.0		SINGLE CRYSTAL 2 MM THICK λ = 3.8		SINGLE CRYSTAL 2 MM THICK λ = 2.8	
300.	0.359	300.	0.531	300.	0.531	300.	0.520
350.	0.337	350.	0.529	350.	0.527	350.	0.518
400.	0.312	400.	0.526	400.	0.525	400.	0.514
425.	0.300	425.	0.525	425.	0.524	425.	0.513
450.	0.287	450.	0.523	450.	0.522	450.	0.512
475.	0.273	475.	0.521	475.	0.520	475.	0.511
500.	0.260	500.	0.514	500.	0.515	500.	0.509
525.	0.245	520.	0.507	520.	0.509	520.	0.507
550.	0.229	540.	0.496	540.	0.500	540.	0.502
575.	0.210	560.	0.483	560.	0.490	560.	0.493
600.	0.189	580.	0.467	580.	0.478	580.	0.482
620.	0.170	600.	0.447	600.	0.464	600.	0.469
640.	0.149	620.	0.424	620.	0.447	620.	0.456
660.	0.123	640.	0.393	640.	0.426	640.	0.439
680.	0.086B†	660.	0.356	660.	0.401	660.	0.419B†
690.	0.060B	680.	0.310B†	680.	0.365B†	680.	0.396B
700.	0.030B	700.	0.257B	700.	0.324B	700.	0.362B
706.	0.000B	720.	0.153B	720.	0.265B	720.	0.302B
		740.	0.000B	740.	0.150B	740.	0.236B
				756.	0.000B	760.	0.120B
						775.	0.000B

† VALUE FOLLOWED BY A "B" IS TYPICAL.

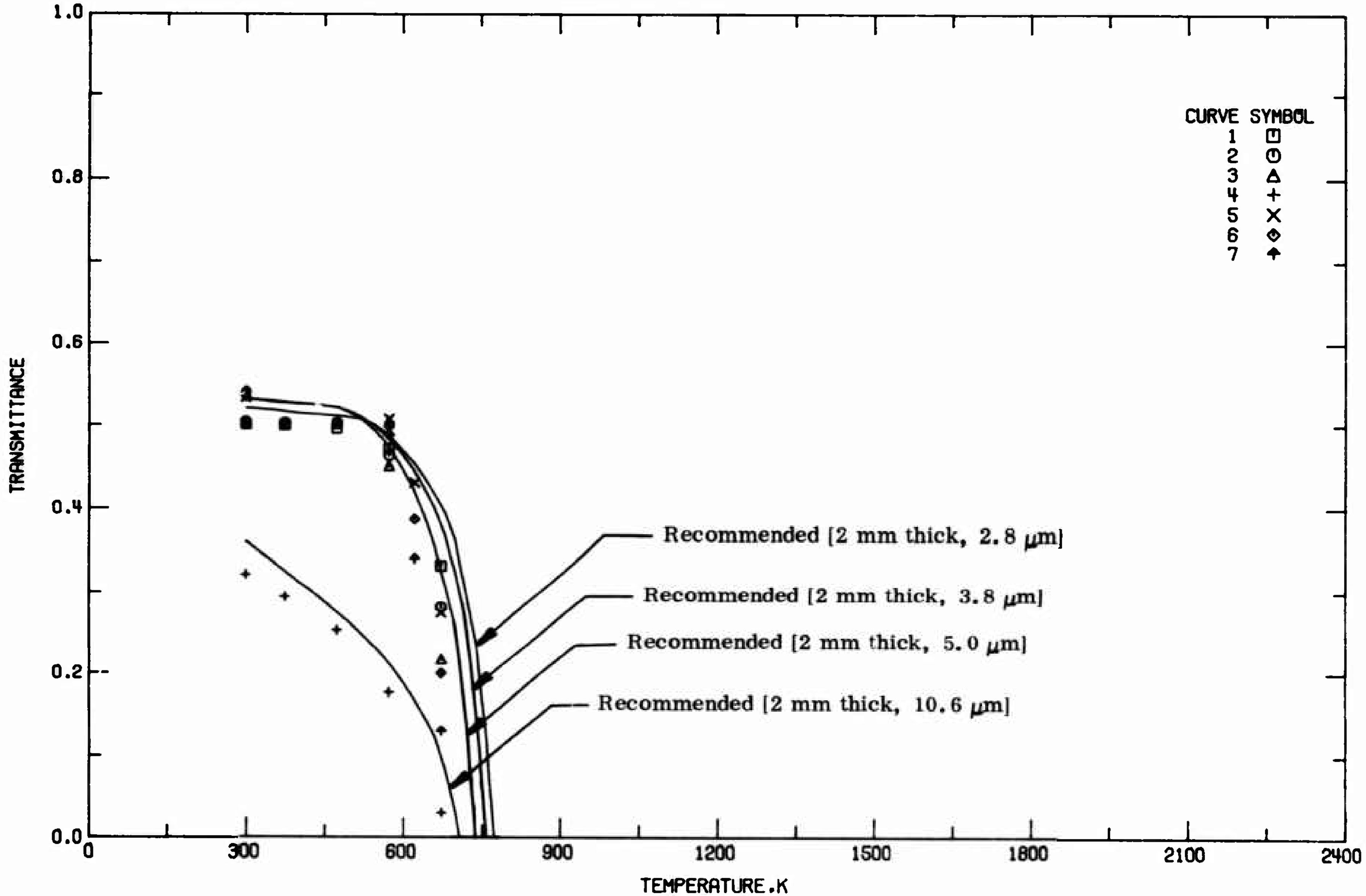


FIGURE 12-12. RECOMMENDED NORMAL SPECTRAL TRANSMITTANCE OF HIGH-RESISTIVITY SILICON (TEMPERATURE DEPENDENCE)

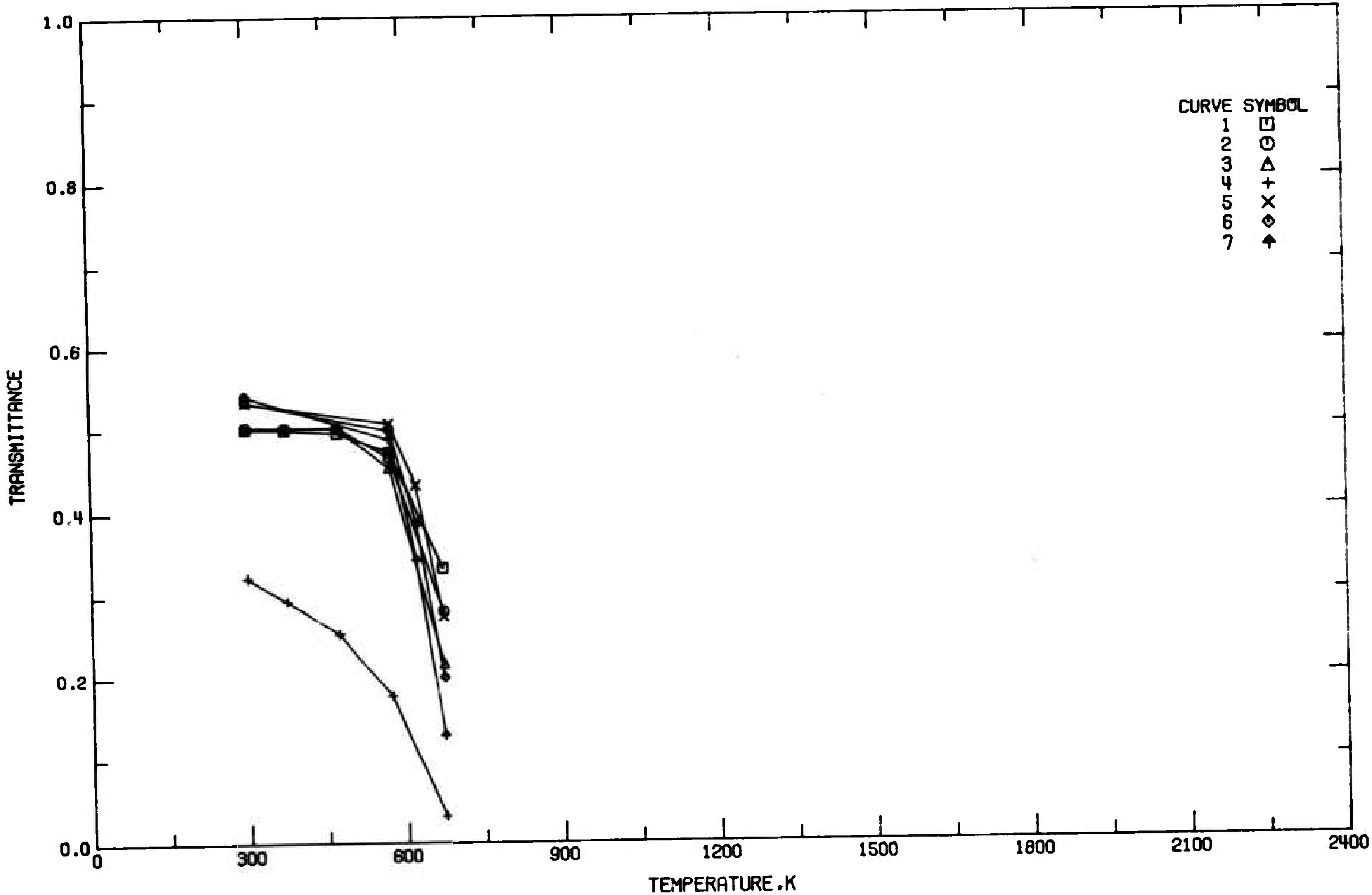


FIGURE 12-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON (TEMPERATURE DEPENDENCE)

TABLE 12-16. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF SILICON (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, µm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T20810	Gillespie, D.T., Olsen, A.L., and Nichols, L.W.	1964	2.8	298–673		n-type single crystal; 6 ppb boron and 20 ppb phosphorous; resistivity 5 ohm-cm; disk 0.110 in. thick and 1.240 in. in diameter; parallelism tolerance of ± 2.5 µm; polished faces; provided by Knapic Electro-Physics, Inc.; measured using Perkin-Elmer 21 spectrophotometer; not corrected for reflection losses; data extracted from spectral curves.
2	T20810	Gillespie, D.T., et al.	1964	3.8	298–673		The above specimen.
3	T20810	Gillespie, D.T., et al.	1964	5.0	298–673		The above specimen.
4	T20810	Gillespie, D.T., et al.	1964	10.6	298–673		The above specimen.
5	T10703	Kraushaar, R.	1958	2.8	293–673		Single crystal silicon; 4.16 mm thick; data extracted from spectral curves.
6	T10703	Kraushaar, R.	1958	3.8	293–673		The above specimen.
7	T10703	Kraushaar, R.	1958	5.0	293–673		The above specimen.

TABLE 12-17. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF HIGH RESISTIVITY SILICON (TEMPERATURE DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

T	τ
CURVE 1 $\lambda = 2.8$	
298.	0.500
373.	0.499
473.	0.495
573.	0.471
673.	0.332
CURVE 2 $\lambda = 3.8$	
298.	0.503
373.	0.502
473.	0.502
573.	0.464
673.	0.281
CURVE 3 $\lambda = 5.0$	
298.	0.503
373.	0.502
473.	0.501
573.	0.451
673.	0.217
CURVE 4 $\lambda = 10.6$	
298.	0.322
373.	0.294
473.	0.253
573.	0.177
673.	0.030
CURVE 5 $\lambda = 2.8$	
298.	0.533
573.	0.507
623.	0.431

T	τ
CURVE 5 (CONT.)	
673.	0.274
CURVE 6 $\lambda = 3.8$	
298.	0.534
573.	0.498
623.	0.386
673.	0.200
CURVE 7 $\lambda = 5.0$	
298.	0.541
573.	0.487
623.	0.341
673.	0.130

4.13. Silicon Carbide

Silicon carbide is usually fabricated by heating carbon and silica sand in an oven. The material is a bluish-black iridescent crystal with hexagonal or cubic structure. The molecular weight is 40.10. The theoretical density is 3.217 g cm^{-3}. It sublimates by decomposition at >2400 K. It is one of the hardest substances in existence, measuring about 9 on Mohs scale hardness. Its fiber has a tensile strength of 3,000,000 psi. The thermal conductivity of a very pure and very dense silicon carbide specimen is comparable to that of metals in the neighborhood of room temperature. The coefficient of linear thermal expansion is about 4×10^{-6} K^{-1}. This substance is soluble in fused alkalies, but is insoluble in water or alcohol.

Silicon carbide is widely used as high refractory material. Its high purity single crystals are used as semiconductors, especially at high temperature applications. Its fibers are used as reinforcement material with plastics.

Industries manufacture various forms of silicon carbide. One of them is carborundum. Optically, carborundum crystallites in various sizes appear from transparent to opaque, and from colorless to deep blue-black. The density ranges from 3.06 to 3.20 g cm^{-3}. It oxidizes slowly above 1273 K. It is commonly used for grinding and polishing. Globar is another form of silicon carbide which is widely used as a source of infrared energy. Its working temperature is up to 1783 K, and may be extended to 1922 K for a short period of time. The coefficient of thermal expansion is low. The structure is not affected by quick heating or abrupt cooling. Its electrical resistivity remains almost constant at above 755 K. It is an excellent material for resistors and heating elements.

a. Normal Spectral Emittance (Wavelength Dependence)

A total of 23 sets of data are available. Most of them were measured in the range of about 1 μm to 15 μm. Measuring temperature ranges from 755 K to 2500 K.

All the data sets show a deep minimum at about 12.6 μm, and all except the data of Blau and Jasperse [T32045] (Figure 13-2, curves 3-6) have a shallow minimum at about 9.2 μm. A rather small peak is located around 10.4 μm. No obvious reason is conceived to account for this difference. For many data sets the values tapered off below 3 μm. This behavior was probably caused by the oxidation of the specimens and by the error in matching the temperature of the specimen and the blackbody standard [T20946]. The specimen was as thin as 100 μm (Figure 13-2, curves 16-18), but the data show no apparent differences compared to that of the thick specimens.

One curve is recommended for the Globar from Carborundum Company. The curve conforms to the data of Mitchell [T25673] (Figure 13-2, curve 9), except between 2 and 6 μm, where the curve follows the shape of Silverman's data [T00758] (Figure 13-2, curve 1) corrected by Morris [T20946]. A shallow minimum around 4 μm is interpreted as caused by a slight oxidation of the specimen in normal circumstances, i.e., the specimen has never been heated in air at elevated temperature over an extended period. The values are recommended for the specimen temperature of 1400 K. Two parallel curves were generated for room temperature and 2400 K. The values at 1400 K are believed to be accurate to within 5% of the true values. For other temperatures, the same set of values are believed to have an uncertainty of 5 to 10% above 700 K, and 10 to 15% below 700 K.

One more curve is presented as provisional for a roughly polished bulk specimen. The curve follows the data of Stewart and Richman [T08277, T40798] (Figure 13-2, curves 11-14 and 19-22). Since the specimens are not well-defined, the values cannot be applied accurately to any polished specimen. The provisional values are applicable to averagely polished specimens at 1000 K, and two parallel curves were generated for room temperature and 2400 K. The uncertainty of these values may be up to 20 to 30% for some specimens.

For thin films with thickness in the order of 10^{-1} μm or thinner, they have very low emittance values between 1 and 15 μm. No recommendation is made due to lack of data.

The recommended and the provisional curves are shown in Figure 13-1 and the experimental curves are shown in Figure 13-2. The recommended values, the experimental measurement information, and the experimental data are tabulated in Tables 13-1, 13-2, and 13-3, respectively.

TABLE 13-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

λ	ϵ	λ	ϵ	λ	ϵ	λ	ϵ	λ	ϵ	λ	ϵ
GLOBAR, BULK OXIDIZED T = 293		GLOBAR, BULK OXIDIZED T = 293 (CONT.)		GLOBAR, BULK OXIDIZED T = 1400		GLOBAR, BULK OXIDIZED T = 1400 (CONT.)		GLOBAR, BULK OXIDIZED T = 2400		GLOBAR, BULK OXIDIZED T = 2400 (CONT.)	
1.0	0.901	10.6	0.872	1.0	0.928	10.6	0.899	1.0	0.951	10.6	0.922
1.2	0.898	10.8	0.869	1.2	0.925	10.8	0.896	1.2	0.948	10.8	0.919
1.5	0.893	11.0	0.862	1.5	0.920	11.0	0.889	1.5	0.943	11.0	0.912
1.8	0.887	11.2	0.855	1.8	0.914	11.2	0.882	1.8	0.937	11.2	0.905
2.0	0.882	11.5	0.841	2.0	0.909	11.5	0.868	2.0	0.932	11.5	0.891
2.2	0.876	11.8	0.826	2.2	0.903	11.8	0.853	2.2	0.926	11.8	0.876
2.5	0.868	12.0	0.815	2.5	0.895	12.0	0.842	2.5	0.918	12.0	0.865
2.8	0.862	12.2	0.806	2.8	0.889	12.2	0.833	2.8	0.912	12.2	0.856
3.0	0.859	12.5	0.795	3.0	0.886	12.5	0.822	3.0	0.909	12.5	0.845
3.2	0.856	12.8	0.793	3.2	0.883	12.8	0.820	3.2	0.906	12.8	0.843
3.5	0.855	13.0	0.798	3.5	0.882	13.0	0.825	3.5	0.905	13.0	0.848
3.8	0.855	13.2	0.804	3.8	0.882	13.2	0.831	3.8	0.905	13.2	0.854
4.0	0.859	13.5	0.813	4.0	0.886	13.5	0.840	4.0	0.909	13.5	0.863
4.2	0.863	13.8	0.821	4.2	0.890	13.8	0.848	4.2	0.913	13.8	0.871
4.5	0.870	14.0	0.825	4.5	0.897	14.0	0.852	4.5	0.920	14.0	0.875
4.8	0.876	14.2	0.829	4.8	0.903	14.2	0.856	4.8	0.926	14.2	0.879
5.0	0.879	14.5	0.831	5.0	0.906	14.5	0.858	5.0	0.929	14.5	0.881
5.2	0.881	14.8	0.833	5.2	0.908	14.8	0.860	5.2	0.931	14.8	0.883
5.5	0.880	15.0	0.833	5.5	0.907	15.0	0.860	5.5	0.930	15.0	0.883
5.8	0.879			5.8	0.906			5.8	0.929		
6.0	0.878			6.0	0.905			6.0	0.928		
6.2	0.877			6.2	0.904			6.2	0.927		
6.5	0.877			6.5	0.904			6.5	0.927		
6.8	0.878			6.8	0.905			6.8	0.928		
7.0	0.878			7.0	0.905			7.0	0.928		
7.2	0.878			7.2	0.905			7.2	0.928		
7.5	0.877			7.5	0.904			7.5	0.927		
7.8	0.876			7.8	0.903			7.8	0.926		
8.0	0.875			8.0	0.902			8.0	0.925		
8.2	0.873			8.2	0.900			8.2	0.923		
8.5	0.871			8.5	0.898			8.5	0.921		
8.8	0.869			8.8	0.896			8.8	0.919		
9.0	0.867			9.0	0.894			9.0	0.917		
9.2	0.865			9.2	0.892			9.2	0.915		
9.5	0.864			9.5	0.891			9.5	0.914		
9.8	0.866			9.8	0.893			9.8	0.916		
10.0	0.869			10.0	0.896			10.0	0.919		
10.2	0.871			10.2	0.898			10.2	0.921		
10.5	0.873			10.5	0.900			10.5	0.923		

TABLE 13-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
BULK POLISHED T = 293		BULK POLISHED T = 293 (CONT.)		BULK POLISHED T = 1000		BULK POLISHED T = 1000 (CONT.)		BULK POLISHED T = 2400		BULK POLISHED T = 2400 (CONT.)	
1.0	0.597A†	10.6	0.791A†	1.0	0.614A†	10.6	0.798A†	1.0	0.647A†	10.6	0.831A†
1.2	0.613A	10.8	0.776A	1.2	0.630A	10.8	0.793A	1.2	0.663A	10.8	0.826A
1.5	0.636A	11.0	0.765A	1.5	0.653A	11.0	0.782A	1.5	0.686A	11.0	0.815A
1.8	0.658A	11.2	0.749A	1.8	0.675A	11.2	0.766A	1.8	0.708A	11.2	0.799A
2.0	0.672A	11.5	0.721A	2.0	0.689A	11.5	0.738A	2.0	0.722A	11.5	0.771A
2.2	0.686A	11.8	0.693A	2.2	0.703A	11.8	0.710A	2.2	0.736A	11.8	0.743A
2.5	0.705A	12.0	0.675A	2.5	0.722A	12.0	0.692A	2.5	0.755A	12.0	0.725A
2.8	0.721A	12.2	0.657A	2.8	0.738A	12.2	0.674A	2.8	0.771A	12.2	0.707A
3.0	0.731A	12.5	0.638A	3.0	0.748A	12.5	0.655A	3.0	0.781A	12.5	0.688A
3.2	0.738A	12.6	0.637A	3.2	0.755A	12.6	0.654A	3.2	0.788A	12.6	0.687A
3.5	0.748A	12.8	0.645A	3.5	0.765A	12.8	0.662A	3.5	0.798A	12.8	0.695A
3.8	0.754A	13.0	0.662A	3.8	0.771A	13.0	0.679A	3.8	0.804A	13.0	0.712A
4.0	0.756A	13.2	0.682A	4.0	0.773A	13.2	0.699A	4.0	0.806A	13.2	0.732A
4.2	0.758A	13.3	0.690A	4.2	0.775A	13.3	0.707A	4.2	0.808A	13.3	0.740A
4.5	0.759A	13.5	0.698A	4.5	0.776A	13.5	0.715A	4.5	0.809A	13.5	0.748A
4.8	0.759A	13.8	0.700A	4.8	0.776A	13.8	0.717A	4.8	0.809A	13.8	0.750A
5.0	0.759A	14.0	0.701A	5.0	0.776A	14.0	0.718A	5.0	0.809A	14.0	0.751A
5.2	0.759A	14.2	0.701A	5.2	0.776A	14.2	0.718A	5.2	0.809A	14.2	0.751A
5.5	0.758A	14.5	0.700A	5.5	0.775A	14.5	0.717A	5.5	0.808A	14.5	0.750A
5.8	0.757A	14.8	0.699A	5.8	0.774A	14.8	0.716A	5.8	0.807A	14.8	0.749A
6.0	0.756A	15.0	0.698A	6.0	0.773A	15.0	0.715A	6.0	0.806A	15.0	0.748A
6.2	0.754A			6.2	0.771A			6.2	0.804A		
6.5	0.752A			6.5	0.769A			6.5	0.802A		
6.8	0.750A			6.8	0.767A			6.8	0.800A		
7.0	0.748A			7.0	0.765A			7.0	0.798A		
7.2	0.747A			7.2	0.764A			7.2	0.797A		
7.5	0.745A			7.5	0.762A			7.5	0.795A		
7.8	0.740A			7.8	0.757A			7.8	0.790A		
8.0	0.737A			8.0	0.754A			8.0	0.787A		
8.2	0.734A			8.2	0.751A			8.2	0.784A		
8.5	0.726A			8.5	0.743A			8.5	0.776A		
8.8	0.716A			8.8	0.733A			8.8	0.766A		
9.0	0.708A			9.0	0.725A			9.0	0.758A		
9.2	0.706A			9.2	0.723A			9.2	0.756A		
9.5	0.718A			9.5	0.735A			9.5	0.768A		
9.8	0.741A			9.8	0.758A			9.8	0.791A		
10.0	0.760A			10.0	0.777A			10.0	0.810A		
10.2	0.774A			10.2	0.791A			10.2	0.824A		
10.5	0.782A			10.5	0.799A			10.5	0.832A		

† VALUE FOLLOWED BY AN "A" IS PROVISIONAL.

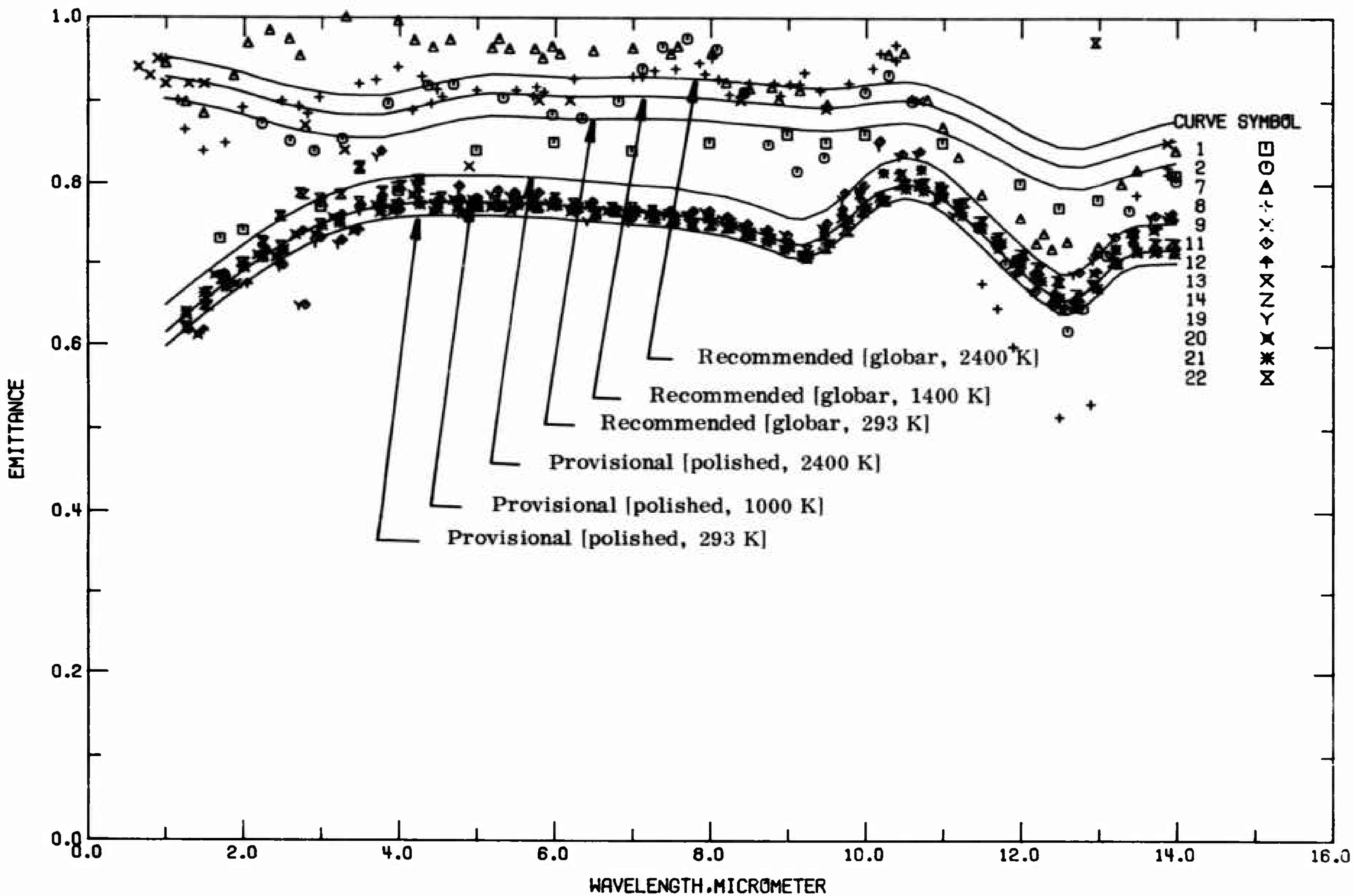


FIGURE 13-1. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE).

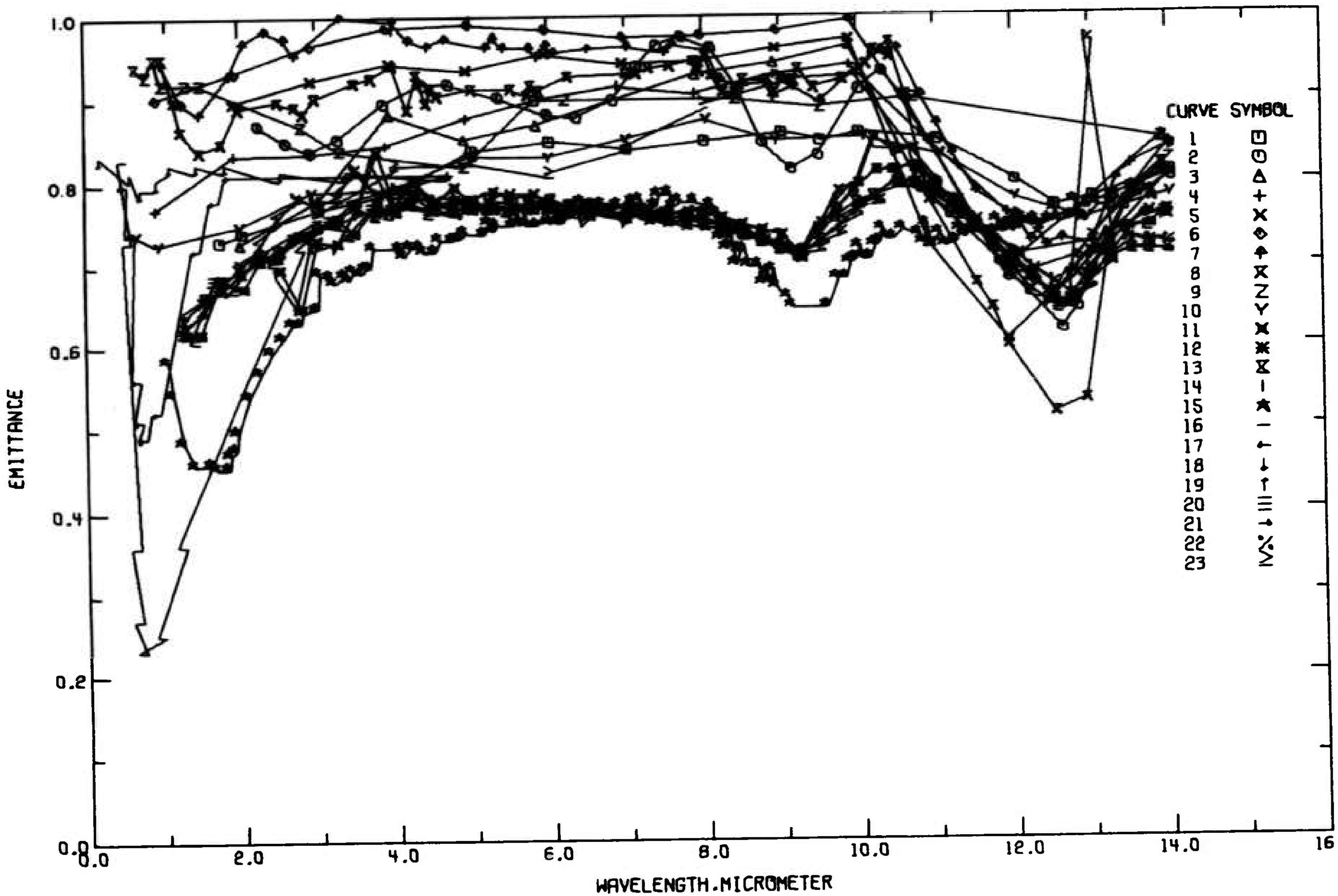


FIGURE 13-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE).

TABLE 13-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF SILICON MONOCARBIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T00758	Silverman, S.	1948	1.7-15.0	1375		Globar from the Carborundum Co.; data extracted from smooth curve; $\theta' = \sim 0°$.
2	T10461	Blau, H.H., Jr., Chaffee, E., and Jasperse, J.R.	1960	2.24-13.9	1296		Norton Co. Crystalon-R; flat and smooth surface obtained by diamond wheel cutting; oxidized by heating in air at 1400 K for 1 hr; measured in argon-hydrogen atm; data extracted from smooth curve; $\theta' = \sim 0°$.
3	T32045	Blau, H.H., Jr. and Jasperse, J.R.	1964	2.00-13.9	873		Bonded Norton RC 4237; 80 pure SiC, nitride bonded; ultrasonically machined; measured in air; $\theta' = 0°$; reported error $\leq 4\%$.
4	T32045	Blau, H.H., Jr. and Jasperse, J.R.	1964	0.91-13.9	1293		Above specimen and conditions.
5	T32045	Blau, H.H., Jr. and Jasperse, J.R.	1964	1.92-13.9	873		Norton Crystalon R; 99 pure; ultrasonically machined; measured in air; $\theta' = 0°$; reported error $\leq 4\%$.
6	T32045	Blau, H.H., Jr. and Jasperse, J.R.	1964	0.92-13.9	1298		Above specimen and conditions.
7	T22272	Schatz, E.A., Goldberg, D.M., Pearson, E.G., and Burks, T.L.	1963	1.00-15.0	1023	Sample No. 102	Density 2.32 g cm^{-3}; theoretical density 3.21 g cm^{-3}; data extracted from smooth curve; $\theta' = \sim 0°$.
8	T22272	Schatz, E.A., et al.	1963	1.00-15.0	1023	Sample No. 103	Sintered at 2173 K for 1 hr (setter material SiC); density 1.49 g cm^{-3}; theoretical density 3.21 g cm^{-3}; data extracted from smooth curve; $\theta' = \sim 0°$.
9	T25673	Mitchell, C.A.	1962	0.65-14.9	1358		Globar from Carborundum Co; $\theta' = \sim 0°$.
10	T02147	Brügel, W.	1950	0.66-15	1243		Rod specimen electrically heated.
11	T40798	Stewart, J.E. and Richman, J.C.	1957	2.5-15	755	Globar	Recrystallized; measured with a Perkin-Elmer spectrophotometer.
12	T40798	Stewart, J.E. and Richman, J.C.	1957	1.3-15	922	Globar	The above specimen.
13	T40798	Stewart, J.E. and Richman, J.C.	1957	1.3-15	1089	Globar	The above specimen.
14	T40798	Stewart, J.E. and Richman, J.C.	1957	1.3-15	1255	Globar	The above specimen.
15	T36117	Schatz, E.A.	1962	1.0-15	1273		Supplied by Carborundum Co.; sintered; density 2.32 g cm^{-3}.
16	T62013	Dubrovskii, G.B.	1969	0.49-4.7	2000		α-phase 6H type single crystal; 100 μ thick plate specimen with surface perpendicular to c_6-axis; values calculated from absorption coefficient measurement; data taken from smooth curve.
17	T62013	Dubrovskii, G.B.	1969	0.49-4.7	2200		The above specimen.
18	T62013	Dubrovskii, G.B.	1969	0.19-4.7	2500		The above specimen.
19	T08277	Richmond, J.C. and Stewart, J.E.	1959	2.5-15	755		Recrystallized rod specimen.
20	T08277	Richmond, J.C. and Stewart, J.E.	1959	1.3-15	922		The above specimen.
21	T08277	Richmond, J.C. and Stewart, J.E.	1959	1.3-15	1089		The above specimen.

TABLE 13-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF SILICON MONOCARBIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
22	T08277	Richmond, J.C. and Stewart, J.E.	1959	1.3-15	1255		The above specimen.
23	T16606	Blau, H.H., Jr., March, J.B., Martin, W.S., Jasperse, J.R., and Chaffee, E.	1960	2.0-14	1073		The same specimen as for curve No. 5.

TABLE 13-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

CURVE 1
T = 1375.

λ	ε
1.7	0.73
2.0	0.74
3.0	0.77
4.0	0.79
5.0	0.84
6.0	0.85
7.0	0.84
8.0	0.85
9.0	0.86
9.5	0.85
10.0	0.86
11.0	0.85
12.0	0.80
12.5	0.77
13.0	0.78
14.0	0.81
15.0	0.79

CURVE 2
T = 1296.

λ	ε
2.24	0.872
2.60	0.851
2.91	0.839
3.27	0.854
3.86	0.896
4.37	0.918
4.70	0.919
5.34	0.903
5.97	0.883
6.35	0.879
6.82	0.899
7.13	0.938
7.39	0.964
7.71	0.974
8.09	0.961
8.44	0.910
8.75	0.848
9.12	0.815

CURVE 2 (CONT.)

λ	ε
9.47	0.832
10.0	0.910
10.3	0.931
10.6	0.899
11.8	0.700
12.6	0.617
12.8	0.644
13.1	0.711
13.4	0.767
14.0	0.803

CURVE 3
T = 873.

λ	ε
2.00	0.727
3.02	0.781
3.93	0.884
4.90	0.853
5.83	0.870
7.88	0.928
8.90	0.942
9.88	0.963
10.8	0.791
11.9	0.694
12.9	0.771
13.9	0.852

CURVE 4
T = 1293.

λ	ε
0.910	0.770
1.93	0.834
2.93	0.836
3.89	0.846
4.92	0.878
5.86	0.900
6.88	0.915
7.88	0.906
8.90	0.927
9.88	0.939

CURVE 4 (CONT.)

λ	ε
10.9	0.848
11.9	0.761
12.3	0.744
14.0	0.80E

CURVE 5
T = 873.

λ	ε
1.92	0.897
2.93	0.923
3.95	0.943
4.94	0.934
5.95	0.954
6.95	0.942
7.91	0.944
8.93	0.960
9.88	0.971
10.9	0.723
11.9	0.604
12.8	0.685
14.0	0.807

CURVE 6
T = 1298.

λ	ε
0.92	0.903
1.94	0.932
2.93	0.965
3.91	0.986
4.96	0.990
5.95	0.984
6.96	0.974
7.95	0.976
8.94	0.981
9.89	0.994
10.9	0.849
11.9	0.680
12.8	0.70E
14.0	0.844

CURVE 7
T = 1023.

λ	ε
1.00	0.945
1.26	0.898
1.49	0.885
1.88	0.930
2.06	0.969
2.34	0.984
2.59	0.974
2.73	0.954
3.32	1.000
3.99	0.995
4.20	0.972
4.44	0.964
4.66	0.973
5.20	0.963
5.29	0.974
5.42	0.962
5.75	0.962
5.85	0.951
5.97	0.965
6.07	0.956
6.50	0.960
7.01	0.963
7.50	0.956
7.59	0.965
8.03	0.958
8.21	0.922
8.51	0.915
8.80	0.917
8.89	0.902
9.16	0.913
9.51	0.896
10.3	0.956
10.5	0.958
10.8	0.902
11.0	0.869
11.2	0.833
11.5	0.787
12.0	0.758
12.2	0.726

CURVE 7 (CONT.)

λ	ε
12.3	0.738
12.4	0.719
12.6	0.728
13.0	0.722
13.3	0.800
13.5	0.817
14.0	0.841
14.5	0.852
15.0	0.880

CURVE 8
T = 1023.

λ	ε
1.00	0.950
1.16	0.900
1.25	0.865
1.49	0.839
1.77	0.849
1.99	0.891
2.50	0.899
2.72	0.893
2.83	0.884
2.98	0.903
3.49	0.920
3.71	0.925
3.99	0.940
4.18	0.888
4.30	0.929
4.42	0.896
4.49	0.913
4.56	0.904
5.00	0.912
5.51	0.912
5.73	0.905
5.77	0.916
5.87	0.910
6.25	0.926
7.01	0.929
7.13	0.929
7.29	0.936

CURVE 8 (CONT.)

λ	ε
7.56	0.938
7.87	0.945
7.94	0.932
8.03	0.951
8.11	0.926
8.25	0.907
8.42	0.907
8.51	0.921
8.83	0.921
8.91	0.906
9.03	0.920
9.16	0.920
9.22	0.934
9.42	0.912
9.79	0.921
10.1	0.939
10.2	0.957
10.4	0.948
10.4	0.967
10.6	0.903
10.9	0.777
11.5	0.675
11.7	0.644
11.9	0.598
12.5	0.514
12.9	0.530
13.2	0.714
13.5	0.786
13.9	0.819
13.9	0.811
14.1	0.826
14.4	0.826
14.5	0.843
14.6	0.834
15.0	0.870

CURVE 9
T = 1358.

λ	ε
0.65	0.94

TABLE 13-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE 9 (CONT.)		CURVE 11 (CONT.)		CURVE 11 (CONT.)		CURVE 12 (CONT.)		CURVE 13 (CONT.)		CURVE 13 (CONT.)	
0.80	0.93	2.80	0.647	12.76	0.690	7.77	0.762	2.26	0.708	12.46	0.658
0.90	0.95	3.00	0.731	12.97	0.712	7.99	0.756	2.48	0.721	12.69	0.647
1.00	0.92	3.27	0.728	13.22	0.734	8.23	0.747	2.99	0.748	12.94	0.672
1.30	0.92	3.52	0.772	13.47	0.742	8.48	0.737	3.23	0.753	13.19	0.703
1.50	0.92	3.78	0.839	13.74	0.761	8.74	0.728	3.49	0.776	13.50	0.714
2.80	0.87	4.01	0.775	13.97	0.756	8.96	0.718	3.75	0.762	13.72	0.714
3.3	0.84	4.27	0.804	14.23	0.760	9.23	0.708	3.96	0.772	13.97	0.714
4.9	0.82	4.50	0.775	14.43	0.766	9.47	0.744	4.25	0.776	14.21	0.714
5.8	0.90	4.78	0.796	14.69	0.759	9.71	0.768	4.47	0.771	14.47	0.725
6.2	0.90	4.99	0.781	14.97	0.740	9.93	0.789	4.75	0.767	14.69	0.717
8.4	0.90	5.28	0.791	15.22	0.740	10.23	0.813	5.00	0.772	14.93	0.722
9.5	0.89	5.49	0.788			10.44	0.813	5.24	0.778		
10.7	0.90	5.80	0.788	CURVE 12		10.72	0.817	5.50	0.778	CURVE 14	
13.9	0.85	6.00	0.780	T = 922.		10.97	0.797	5.74	0.776	T = 1255.	
14.9	0.86	6.29	0.774			11.21	0.776	6.01	0.782		
		6.53	0.760	1.30	0.616	11.49	0.749	6.24	0.775	1.26	0.620
CURVE 10		6.78	0.769	1.49	0.616	11.72	0.720	6.49	0.770	1.54	0.646
T = 1243.		7.00	0.757	1.76	0.686	11.96	0.707	6.74	0.770	1.77	0.678
		7.25	0.763	2.05	0.673	12.20	0.686	7.00	0.770	2.01	0.700
0.66	0.739	7.53	0.763	2.29	0.715	12.44	0.663	7.26	0.767	2.26	0.725
0.95	0.726	7.79	0.766	2.49	0.711	12.57	0.645	7.53	0.758	2.48	0.758
2.00	0.749	8.00	0.766	2.77	0.739	12.70	0.653	7.76	0.758	2.78	0.785
2.93	0.790	8.23	0.759	3.27	0.760	12.98	0.690	7.99	0.756	3.01	0.776
3.97	0.793	8.49	0.750	3.49	0.740	13.22	0.719	8.27	0.751	3.25	0.785
4.97	0.833	8.75	0.743	3.78	0.778	13.43	0.741	8.47	0.744	3.49	0.817
5.99	0.831	9.00	0.736	4.02	0.766	13.76	0.745	8.73	0.734	3.78	0.788
6.99	0.853	9.25	0.710	4.26	0.789	13.96	0.763	8.97	0.725	3.97	0.794
8.02	0.876	9.51	0.751	4.50	0.768	14.20	0.754	9.25	0.717	4.23	0.803
8.93	0.850	9.74	0.789	4.78	0.781	14.45	0.760	9.47	0.734	4.47	0.780
10.06	0.854	9.99	0.798	5.01	0.781	14.75	0.745	9.69	0.757	4.75	0.771
11.05	0.832	10.20	0.853	5.28	0.774	14.98	0.745	9.96	0.775	5.00	0.771
12.00	0.780	10.48	0.837	5.49	0.769	15.21	0.737	10.18	0.783	5.28	0.771
12.93	0.754	10.71	0.840	5.75	0.774			10.49	0.800	5.48	0.775
14.00	0.783	10.97	0.788	6.01	0.774	CURVE 13		10.70	0.797	5.77	0.769
15.00	0.767	11.23	0.764	6.26	0.767	T = 1089.		10.98	0.784	6.00	0.774
		11.49	0.749	6.49	0.777			11.22	0.765	6.26	0.768
CURVE 11		11.71	0.726	6.73	0.767	1.27	0.634	11.46	0.746	6.52	0.761
T = 755.		11.98	0.691	7.30	0.762	1.54	0.663	11.68	0.728	6.79	0.764
		12.19	0.666	7.26	0.766	1.79	0.673	11.94	0.702	6.96	0.764
2.52	0.697	12.45	0.650	7.49	0.766	2.02	0.693	12.22	0.681	7.25	0.757

TABLE 13-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε)

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE 14(CONT.)		CURVE 15(CONT.)		CURVE 15(CONT.)		CURVE 15(CONT.)		CURVE 15(CONT.)		CURVE 16(CONT.)	
7.49	0.753	1.63	0.459	5.62	0.771	8.79	0.682	12.40	0.754	4.69	0.81
7.78	0.747	1.78	0.459	5.66	0.754	8.82	0.697	12.47	0.767		
7.98	0.747	1.80	0.475	5.79	0.754	8.87	0.676	12.53	0.753	CURVE 17	
8.20	0.744	1.88	0.481	5.90	0.774	9.02	0.663	12.69	0.758	T = 2200.	
8.44	0.736	1.90	0.501	5.96	0.756	9.08	0.651	12.73	0.777		
8.72	0.733	2.05	0.543	6.03	0.777	9.53	0.651	12.85	0.753	0.490	0.80
8.99	0.725	2.20	0.572	6.05	0.757	9.66	0.687	13.02	0.773	0.576	0.74
9.19	0.710	2.35	0.598	6.12	0.757	9.77	0.687	13.22	0.773	0.643	0.56
9.45	0.724	2.49	0.615	6.16	0.767	9.82	0.706	13.27	0.782	0.674	0.51
9.72	0.742	2.62	0.633	6.31	0.773	9.89	0.709	13.44	0.777	0.719	0.49
9.95	0.766	2.73	0.633	6.34	0.767	9.94	0.724	13.50	0.793	0.902	0.52
10.20	0.779	2.75	0.647	6.37	0.782	9.99	0.711	13.57	0.783	1.43	0.72
10.44	0.799	2.95	0.652	6.43	0.764	10.08	0.711	13.62	0.793	1.67	0.78
10.69	0.799	2.97	0.696	6.49	0.772	10.14	0.726	13.73	0.787	1.87	0.81
10.97	0.791	3.12	0.693	6.63	0.779	10.20	0.729	13.77	0.779	3.38	0.81
11.20	0.775	3.17	0.684	6.68	0.771	10.24	0.746	14.05	0.783	4.69	0.81
11.46	0.753	3.30	0.694	6.84	0.778	10.31	0.734	14.35	0.788		
11.69	0.732	3.36	0.688	7.03	0.782	10.39	0.734	14.41	0.781	CURVE 18	
11.99	0.712	3.41	0.700	7.06	0.774	10.51	0.746	14.72	0.793	T = 2500.	
12.20	0.696	3.52	0.696	7.12	0.784	10.72	0.739	14.55	0.785		
12.46	0.679	3.58	0.703	7.18	0.773	10.77	0.728	14.72	0.797	0.190	0.83
12.71	0.662	3.63	0.703	7.32	0.777	10.81	0.751	14.77	0.806	0.588	0.81
12.93	0.674	3.67	0.727	7.36	0.790	10.87	0.724	14.83	0.800	0.716	0.79
13.19	0.702	4.02	0.727	7.50	0.792	10.98	0.740	14.87	0.789	0.927	0.80
13.44	0.732	4.07	0.717	7.55	0.776	11.06	0.725	14.93	0.801	1.09	0.82
13.72	0.726	4.15	0.728	7.63	0.782	11.19	0.729	14.96	0.819	1.44	0.82
13.93	0.726	4.28	0.728	7.83	0.782	11.25	0.744	15.00	0.827	1.81	0.82
14.21	0.721	4.33	0.722	8.04	0.777	11.31	0.735			2.52	0.81
14.46	0.721	4.47	0.722	8.12	0.767	11.35	0.740	CURVE 16		3.38	0.81
14.67	0.721	4.53	0.736	8.15	0.736	11.69	0.740	T = 2000.		4.69	0.81
14.95	0.724	4.71	0.736	8.20	0.750	11.73	0.755				
		4.81	0.739	8.24	0.724	11.80	0.740	0.490	0.83	CURVE 19	
CURVE 15		4.86	0.745	8.29	0.737	11.86	0.748	0.546	0.73	T = 755.	
T = 1273.		5.11	0.743	8.35	0.705	11.93	0.741	0.614	0.36		
		5.17	0.757	8.40	0.721	11.97	0.752	0.638	0.27	2.46	0.694
1.00	0.587	5.23	0.746	8.46	0.721	12.01	0.744	0.674	0.23	2.71	0.646
1.07	0.546	5.27	0.754	8.51	0.703	12.06	0.756	0.923	0.25	2.92	0.724
1.20	0.489	5.49	0.754	8.65	0.703	12.14	0.749	1.21	0.36	3.21	0.722
1.35	0.462	5.54	0.766	8.70	0.681	12.22	0.755	2.77	0.72	3.49	0.764
1.56	0.464	5.58	0.756	8.75	0.693	12.27	0.747	3.44	0.78	3.71	0.831

TABLE 13-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
CURVE 19 (CONT.)		CURVE 19 (CONT.)		CURVE 20 (CONT.)		CURVE 21 (CONT.)		CURVE 21 (CONT.)		CURVE 22 (CONT.)	
3.96	0.773	13.88	0.755	8.72	0.727	3.78	0.774	13.50	0.716	8.52	0.736
4.21	0.798	14.23	0.757	8.95	0.718	3.77	0.764	13.75	0.716	8.78	0.731
4.45	0.774	14.39	0.761	9.19	0.709	3.99	0.769	13.98	0.713	9.01	0.723
4.76	0.792	14.73	0.755	9.47	0.740	4.27	0.773	14.23	0.711	9.25	0.708
4.88	0.775	14.90	0.734	9.70	0.764	4.49	0.768	14.51	0.724	9.49	0.720
5.17	0.785	15.21	0.737	9.92	0.787	4.81	0.762	14.73	0.715	9.77	0.741
5.42	0.783			10.23	0.813	5.02	0.770	14.98	0.722	9.97	0.765
5.69	0.781	CURVE 20		10.46	0.813	5.30	0.773			10.26	0.779
5.92	0.775	T = 922.		10.72	0.817	5.52	0.773	CURVE 22		10.52	0.800
6.18	0.768			10.95	0.798	5.76	0.771	T = 1255.		10.76	0.801
6.41	0.752	1.26	0.619	11.19	0.775	6.01	0.775			11.01	0.793
6.68	0.766	1.41	0.611	11.48	0.746	6.30	0.770	1.26	0.619	11.27	0.777
6.94	0.751	1.63	0.684	11.71	0.719	6.52	0.765	1.50	0.647	11.51	0.754
7.18	0.762	1.91	0.673	11.95	0.706	6.76	0.764	1.72	0.679	11.72	0.734
7.40	0.760	2.18	0.710	12.17	0.685	7.04	0.764	1.97	0.700	12.04	0.712
7.69	0.760	2.42	0.707	12.42	0.659	7.29	0.761	2.24	0.727	12.24	0.693
7.92	0.764	2.67	0.735	12.54	0.642	7.55	0.755	2.47	0.759	12.50	0.677
8.15	0.755	2.93	0.735	12.70	0.650	7.76	0.752	2.73	0.787	12.76	0.659
8.43	0.746	3.15	0.757	12.94	0.689	8.04	0.753	2.98	0.781	12.97	0.670
8.70	0.739	3.41	0.739	13.22	0.719	8.29	0.748	3.26	0.786	13.25	0.701
8.95	0.736	3.70	0.772	13.42	0.739	8.52	0.740	3.49	0.820	13.46	0.729
9.18	0.707	3.92	0.765	13.71	0.742	8.77	0.731	3.79	0.790	13.74	0.726
9.44	0.744	4.18	0.785	13.92	0.760	9.02	0.721	4.03	0.797	13.99	0.726
9.69	0.780	4.44	0.765	14.21	0.754	9.27	0.712	4.26	0.804	14.25	0.723
9.91	0.792	4.70	0.779	14.45	0.757	9.54	0.726	4.54	0.783	14.48	0.723
10.17	0.846	4.94	0.779	14.72	0.743	9.78	0.755	4.76	0.773	14.72	0.720
10.43	0.833	5.18	0.770	14.99	0.745	10.01	0.771	5.00	0.771	14.99	0.723
10.66	0.835	5.43	0.766	15.19	0.737	10.22	0.781	5.29	0.771	15.26	0.723
10.90	0.786	5.71	0.771			10.52	0.794	5.53	0.777		
11.12	0.761	5.96	0.771	CURVE 21		10.75	0.791	5.79	0.771	CURVE 23	
11.40	0.747	6.20	0.764	T = 1089.		11.00	0.784	6.03	0.773	T = 1073.	
11.65	0.724	6.44	0.773			11.25	0.761	6.27	0.770		
11.93	0.686	6.68	0.766	1.26	0.639	11.49	0.744	6.52	0.765	2.00	0.699
12.13	0.665	6.95	0.760	1.50	0.662	11.75	0.727	6.79	0.766	3.00	0.761
12.39	0.648	7.21	0.761	1.78	0.669	12.00	0.700	7.02	0.766	4.00	0.821
12.67	0.686	7.45	0.763	2.00	0.694	12.26	0.679	7.29	0.756	5.00	0.825
12.92	0.704	7.72	0.760	2.25	0.706	12.50	0.658	7.53	0.753	6.00	0.810
13.18	0.733	7.98	0.756	2.52	0.716	12.73	0.645	7.77	0.749	7.00	0.842
13.40	0.738	8.23	0.744	3.01	0.746	12.98	0.670	8.01	0.748	8.00	0.892
13.67	0.757	8.49	0.735	3.24	0.750	13.24	0.702	8.25	0.745	9.00	0.921

TABLE 13-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

λ	ϵ
CURVE 23(CONT.)	
10.00	0.929
11.00	0.796
12.00	0.708
13.00	0.726
14.00	0.833

b. Normal Spectral Emittance (Temperature Dependence)

A total of 11 sets of data are available. Five sets of the data were measured below 1 μm. The remaining data were measured between 2 and 12 μm at temperatures ranging from 1000 to 1800 K.

The data measured between 2 and 12 μm show a positive but weak dependence on temperature. This fact is supported by Dubrovskii's measurements [T62013] (Figure 13-2, curves 16-18) at higher temperatures for a single crystal and by Morris' values [T20946] at 395 K for Globar. The temperature dependence is assumed linear for simplicity. The slope is determined by the data of Brügel [T02147] (Figure 13-4, curves 3-6 and 9) and Dubrovskii. Using this slope value, four curves were generated as recommended for Globar at 2.8, 3.8, 5.0, and 10.6 μm from room temperature to 2400 K. The uncertainty is believed to be 5 to 10% below 800 K, 5% from 800 to 1800 K, and 10% above 1800 K. For polished bulk material, four similar curves were generated as provisional. The uncertainty is believed to be as high as 30% for some specimens.

The recommended curves are shown in Figure 13-3 and the experimental curves are shown in Figure 13-4. The recommended values, the experimental measurement information, and the experimental data are tabulated in Tables 13-4, 13-5, and 13-6, respectively.

TABLE 13-4. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ	T	ϵ	T	ϵ	T	ϵ	T	ϵ	T	ϵ
GLOBAR, BULK OXIDIZED λ = 2.8		GLOBAR, BULK OXIDIZED λ = 3.8		GLOBAR, BULK OXIDIZED λ = 5.0		GLOBAR, BULK OXIDIZED λ = 10.6		BULK POLISHED λ = 2.8		BULK POLISHED λ = 3.8	
293.	0.862	293.	0.855	293.	0.879	293.	0.872	293.	0.711A†	293.	0.744A†
300.	0.862	300.	0.855	300.	0.879	300.	0.872	300.	0.711A	300.	0.744A
400.	0.864	400.	0.857	400.	0.881	400.	0.874	400.	0.713A	400.	0.746A
500.	0.867	500.	0.860	500.	0.884	500.	0.877	500.	0.716A	500.	0.749A
600.	0.870	600.	0.863	600.	0.887	600.	0.880	600.	0.719A	600.	0.752A
700.	0.872	700.	0.865	700.	0.889	700.	0.882	700.	0.721A	700.	0.754A
800.	0.874	800.	0.867	800.	0.891	800.	0.884	800.	0.723A	800.	0.756A
900.	0.877	900.	0.870	900.	0.894	900.	0.887	900.	0.726A	900.	0.759A
1000.	0.879	1000.	0.872	1000.	0.896	1000.	0.889	1000.	0.728A	1000.	0.761A
1100.	0.882	1100.	0.875	1100.	0.899	1100.	0.892	1100.	0.731A	1100.	0.764A
1200.	0.884	1200.	0.877	1200.	0.901	1200.	0.894	1200.	0.733A	1200.	0.766A
1300.	0.886	1300.	0.879	1300.	0.903	1300.	0.896	1300.	0.735A	1300.	0.768A
1400.	0.889	1400.	0.882	1400.	0.906	1400.	0.899	1400.	0.738A	1400.	0.771A
1500.	0.891	1500.	0.884	1500.	0.908	1500.	0.901	1500.	0.740A	1500.	0.773A
1600.	0.894	1600.	0.887	1600.	0.911	1600.	0.904	1600.	0.743A	1600.	0.776A
1700.	0.896	1700.	0.889	1700.	0.913	1700.	0.906	1700.	0.745A	1700.	0.778A
1800.	0.898	1800.	0.891	1800.	0.915	1800.	0.908	1800.	0.747A	1800.	0.780A
1900.	0.900	1900.	0.893	1900.	0.917	1900.	0.910	1900.	0.749A	1900.	0.782A
2000.	0.903	2000.	0.896	2000.	0.920	2000.	0.913	2000.	0.752A	2000.	0.785A
2100.	0.906	2100.	0.899	2100.	0.923	2100.	0.916	2100.	0.755A	2100.	0.788A
2200.	0.908	2200.	0.901	2200.	0.925	2200.	0.918	2200.	0.757A	2200.	0.790A
2300.	0.910	2300.	0.903	2300.	0.927	2300.	0.920	2300.	0.759A	2300.	0.792A
2400.	0.912	2400.	0.905	2400.	0.929	2400.	0.922	2400.	0.761A	2400.	0.794A

† VALUE FOLLOWED BY AN "A" IS PROVISIONAL.

TABLE 13-4. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (TEMPERATURE DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ	T	ϵ
BULK POLISHED $\lambda = 5.0$		BULK POLISHED $\lambda = 10.6$	
293.	0.749A†	293.	0.771A†
300.	0.749A	300.	0.771A
400.	0.751A	400.	0.773A
500.	0.754A	500.	0.776A
600.	0.757A	600.	0.779A
700.	0.759A	700.	0.781A
800.	0.761A	800.	0.783A
900.	0.764A	900.	0.786A
1000.	0.766A	1000.	0.788A
1100.	0.769A	1100.	0.791A
1200.	0.771A	1200.	0.793A
1300.	0.773A	1300.	0.795A
1400.	0.776A	1400.	0.798A
1500.	0.778A	1500.	0.800A
1600.	0.781A	1600.	0.803A
1700.	0.783A	1700.	0.805A
1800.	0.785A	1800.	0.807A
1900.	0.787A	1900.	0.809A
2000.	0.790A	2000.	0.812A
2100.	0.793A	2100.	0.815A
2200.	0.795A	2200.	0.817A
2300.	0.797A	2300.	0.819A
2400.	0.799A	2400.	0.821A

† VALUE FOLLOWED BY AN "A" IS PROVISIONAL.

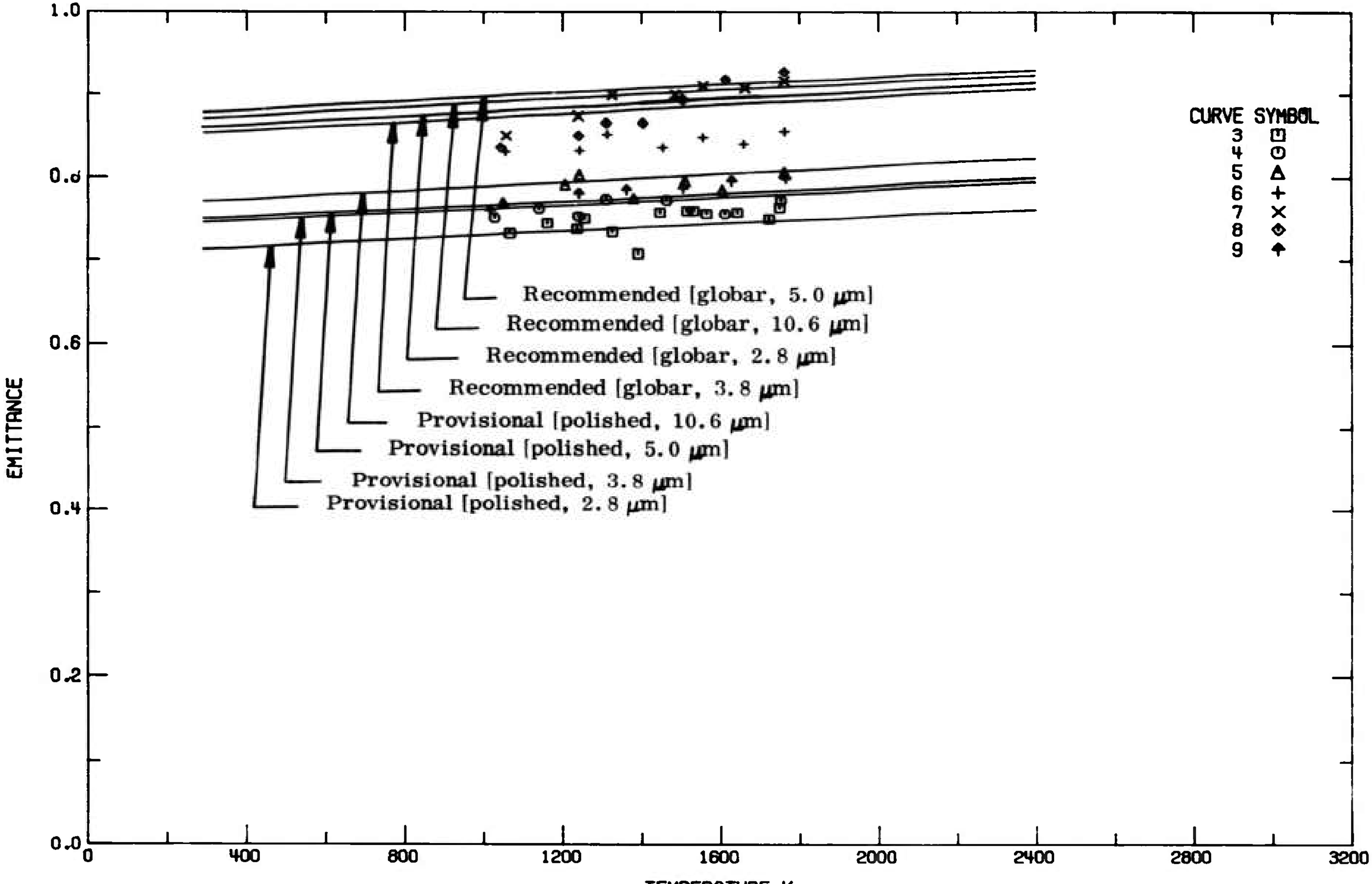


FIGURE 13-3. RECOMMENDED NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (TEMPERATURE DEPENDENCE).

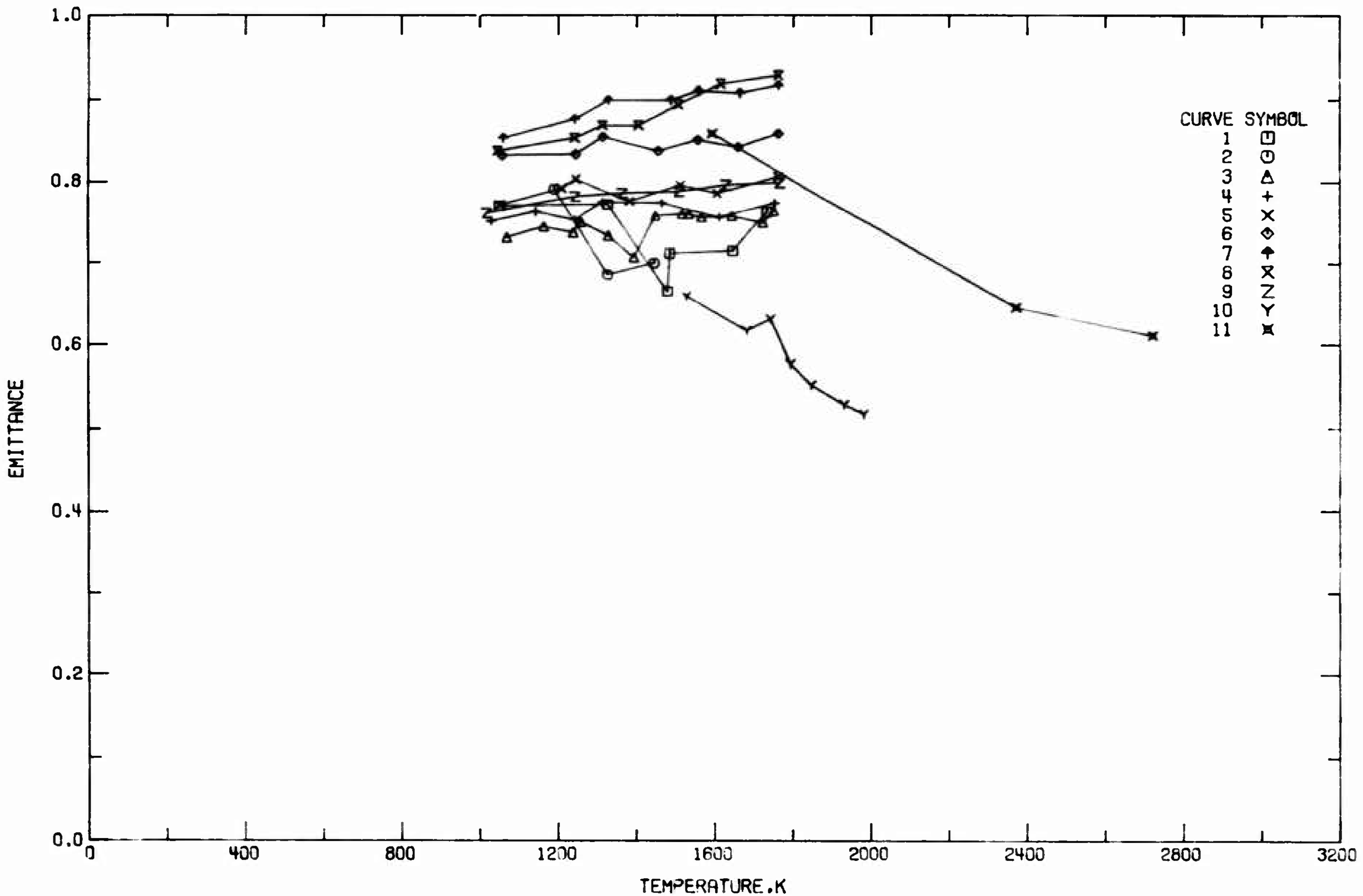


FIGURE 13-4. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (TEMPERATURE DEPENDENCE).

TABLE 13-5. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF SILICON MONOCARBIDE (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T10060	Olson, O.H. and Morris, J.C.	1959	0.665	1050-1736		Cycle 1; $\theta' = \sim 0°$.
2	T10060	Olson, O.H. and Morris, J.C.	1959	0.665	1189-1446		Above specimen and conditions; cycle 2.
3	T02147	Brügel, W.	1950	0.665	1068-1752		Rod specimen electrically heated.
4	T02147	Brügel, W.	1950	2	1028-1755		The above specimen.
5	T02147	Brügel, W.	1950	4	1051-1764		The above specimen.
6	T02147	Brügel, W.	1950	6	1057-1764		The above specimen.
7	T02147	Brügel, W.	1950	8	1059-1764		The above specimen.
8	T02147	Brügel, W.	1950	10	1045-1764		The above specimen.
9	T02147	Brügel, W.	1950	12	1017-1768		The above specimen.
10	T61239	Ko, Y.C.	1969	0.665	1528-1983		Cylindrical specimen 0.25 in. in diameter and 0.5 in. long with a hole 1/16 in. in diameter and 0.25 in. deep in one end; hot-pressed; density 3.1405 g cm^{-3}.
11	T74177	Frantsevich, I.N., Gnesin, G.G., Dyban, Yu.P., Gaiduchenko, A.K., Osovitskii, E.L., and Ostroverkhov, V.I.	1972	0.65	1593-2723		Polycrystalline; sintered; density 3 to 3.05 g cm^{-3}; electrical resistivity 0.1 to 0.4 Ω cm at 293 K and 0.03 to 0.05 Ω cm at 1273 K.

TABLE 13-6. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON CARBIDE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ
CURVE 1	
λ = 0.665	
1050.	0.769
1326.	0.771
1480.	0.664
1485.	0.711
1648.	0.714
1736.	0.762
CURVE 2	
λ = 0.665	
1189.	0.790
1326.	0.685
1446.	0.699
CURVE 3	
λ = 0.665	
1068.	0.730
1163.	0.743
1238.	0.736
1257.	0.749
1328.	0.732
1393.	0.706
1448.	0.757
1517.	0.759
1534.	0.759
1566.	0.755
1645.	0.757
1725.	0.748
1752.	0.763
CURVE 4	
λ = 2.	
1028.	0.750
1141.	0.762
1241.	0.752
1312.	0.774
1465.	0.773

T	ϵ
CURVE 4 (CONT.)	
1612.	0.755
1755.	0.773
CURVE 5	
λ = 4.	
1051.	0.770
1208.	0.791
1244.	0.802
1382.	0.775
1512.	0.795
1607.	0.785
1764.	0.805
CURVE 6	
λ = 6.	
1057.	0.830
1244.	0.831
1314.	0.853
1456.	0.835
1557.	0.849
1661.	0.840
1764.	0.857
CURVE 7	
λ = 8.	
1059.	0.851
1242.	0.875
1328.	0.898
1488.	0.898
1559.	0.909
1665.	0.906
1764.	0.915
CURVE 8	
λ = 10.	
1045.	0.835

T	ϵ
CURVE 8 (CONT.)	
1242.	0.851
1313.	0.867
1405.	0.867
1507.	0.893
1616.	0.917
1764.	0.927
CURVE 9	
λ = 12.	
1017.	0.760
1243.	0.781
1364.	0.785
1508.	0.787
1630.	0.795
1768.	0.798
CURVE 10	
λ = 0.665	
1528.	0.658
1683.	0.616
1745.	0.630
1795.	0.577
1849.	0.552
1933.	0.528
1983.	0.516
CURVE 11	
λ = 0.65	
1593.	0.857
2373.	0.644
2723.	0.610

c. Normal Spectral Reflectance (Wavelength Dependence)

A total of 38 sets of data are available. Fourteen sets were measured on single crystals, two on thin films, and seventeen on compact powder specimens.

Only three sets of data were measured for polycrystalline specimens, and two of them were measured at below 2.7 μm (Figure 13-6, curves 2 and 3). Chang's data [T42979] (Figure 13-6, curve 7) were measured at room temperature from 2 to 30 μm. The specimen was supplied by Carborundum Company, but without any detailed description. The behavior of this set of data is not consistent with any of the emittance data. Thus no recommendation was generated based on the experimental reflectance data. Provisional values were derived from the recommended curves of emittance, assuming the transmittance is negligible, for polished bluk material at 293 K and 2400 K. The error is estimated to be 20 to 30%. A pair of curves were generated the same way for Globar. Since the absolute values of the derived reflectance of Globar are small, they can only be considered as typical.

Provisional values at 293 K were generated in accordance with the data of Spitzer, et al. [T32822] (Figure 13-6, curve 25) for a thin film 0.06 μm thick. The uncertainty is estimated to be 15 to 30%.

The provisional and typical curves are shown in Figure 13-5 and the experimental curves are shown in Figure 13-6. The provisional and typical values, the experimental measurement information, and the experimental data are tabulated in Tables 13-7, 13-8, and 13-9, respectively.

TABLE 13-7. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
BULK POLISHED T = 293		BULK POLISHED T = 293 (CONT.)		BULK POLISHED T = 2400		BULK POLISHED T = 2400 (CONT.)		GLOBAR, BULK OXIDIZED T = 293		GLOBAR, BULK OXIDIZED T = 293 (CONT.)	
1.0	0.403	10.6	0.219	1.0	0.353	10.6	0.169	1.0	0.0998†	10.6	0.1288†
1.2	0.387	10.8	0.224	1.2	0.337	10.8	0.174	1.2	0.1028	10.8	0.1318
1.5	0.364	11.0	0.235	1.5	0.314	11.0	0.185	1.5	0.1078	11.0	0.1388
1.8	0.342	11.2	0.251	1.8	0.292	11.2	0.201	1.8	0.1138	11.2	0.1458
2.0	0.328	11.5	0.279	2.0	0.278	11.5	0.229	2.0	0.1188	11.5	0.1598
2.2	0.314	11.8	0.307	2.2	0.264	11.8	0.257	2.2	0.1248	11.8	0.1748
2.5	0.295	12.0	0.325	2.5	0.245	12.0	0.275	2.5	0.1328	12.0	0.1858
2.8	0.279	12.2	0.343	2.8	0.229	12.2	0.293	2.8	0.1388	12.2	0.1948
3.0	0.269	12.5	0.362	3.0	0.219	12.5	0.312	3.0	0.1418	12.5	0.2058
3.2	0.262	12.6	0.363	3.2	0.212	12.6	0.313	3.2	0.1448	12.8	0.2078
3.5	0.252	12.8	0.355	3.5	0.202	12.8	0.305	3.5	0.1458	13.0	0.2028
3.8	0.246	13.0	0.338	3.8	0.196	13.0	0.288	3.8	0.1458	13.2	0.1968
4.0	0.244	13.2	0.318	4.0	0.194	13.2	0.268	4.0	0.1418	13.5	0.1878
4.2	0.242	13.3	0.310	4.2	0.192	13.3	0.260	4.2	0.1378	13.8	0.1798
4.5	0.241	13.5	0.302	4.5	0.191	13.5	0.252	4.5	0.1308	14.0	0.1758
4.8	0.241	13.8	0.300	4.8	0.191	13.8	0.250	4.8	0.1248	14.2	0.1718
5.0	0.241	14.0	0.299	5.0	0.191	14.0	0.249	5.0	0.1218	14.5	0.1698
5.2	0.241	14.2	0.299	5.2	0.191	14.2	0.249	5.2	0.1198	14.8	0.1678
5.5	0.242	14.5	0.300	5.5	0.192	14.5	0.250	5.5	0.1208	15.0	0.1678
5.8	0.243	14.8	0.301	5.8	0.193	14.8	0.251	5.8	0.1218		
6.0	0.244	15.0	0.302	6.0	0.194	15.0	0.252	6.0	0.1228		
6.2	0.246			6.2	0.196			6.2	0.1238		
6.5	0.248			6.5	0.198			6.5	0.1238		
6.8	0.250			6.8	0.200			6.8	0.1228		
7.0	0.252			7.0	0.202			7.0	0.1228		
7.2	0.253			7.2	0.203			7.2	0.1228		
7.5	0.255			7.5	0.205			7.5	0.1238		
7.8	0.260			7.8	0.210			7.8	0.1248		
8.0	0.263			8.0	0.213			8.0	0.1258		
8.2	0.266			8.2	0.216			8.2	0.1278		
8.5	0.274			8.5	0.224			8.5	0.1298		
8.8	0.284			8.8	0.234			8.8	0.1318		
9.0	0.292			9.0	0.242			9.0	0.1338		
9.2	0.294			9.2	0.244			9.2	0.1358		
9.5	0.282			9.5	0.232			9.5	0.1368		
9.8	0.259			9.8	0.209			9.8	0.1348		
10.0	0.240			10.0	0.190			10.0	0.1318		
10.2	0.226			10.2	0.176			10.2	0.1298		
10.5	0.218			10.5	0.168			10.5	0.1278		

† VALUE FOLLOWED BY A "B" IS TYPICAL.

TABLE 13-7. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
GLOBAR, BULK OXIDIZED T = 2400		GLOBAR, BULK OXIDIZED T = 2400 (CONT.)		THIN FILM THICKNESS 0.06 T = 293		THIN FILM THICKNESS 0.06 T = 293 (CONT.)		THIN FILM THICKNESS 0.06 T = 293 (CONT.)	
1.0	0.0498B†	10.6	0.0788B†	1.0	0.447	9.8	0.016	14.5	0.083
1.2	0.0528B	10.8	0.0818B	1.1	0.415	10.0	0.016	14.8	0.078
1.5	0.0578B	11.0	0.0888B	1.2	0.387	10.2	0.016	15.0	0.076
1.8	0.0638B	11.2	0.0958B	1.3	0.361	10.5	0.017		
2.0	0.0688B	11.5	0.1098B	1.4	0.336	10.6	0.018		
2.2	0.0748B	11.8	0.1248B	1.5	0.316	10.8	0.019		
2.5	0.0828B	12.0	0.1358B	1.6	0.298	11.0	0.022		
2.8	0.0888B	12.2	0.1448B	1.8	0.262	11.2	0.028		
3.0	0.0918B	12.5	0.1558B	2.0	0.232	11.4	0.040		
3.2	0.0948B	12.8	0.1578B	2.2	0.206	11.5	0.049		
3.5	0.0958B	13.0	0.1528B	2.5	0.174	11.6	0.059		
3.8	0.0958B	13.2	0.1468B	2.8	0.149	11.7	0.073		
4.0	0.0918B	13.5	0.1378B	3.0	0.136	11.8	0.091		
4.2	0.0878B	13.8	0.1298B	3.2	0.125	11.9	0.122		
4.5	0.0808B	14.0	0.1258B	3.5	0.111	12.0	0.190		
4.8	0.0748B	14.2	0.1218B	3.8	0.099	12.1	0.298		
5.0	0.0718B	14.5	0.1198B	4.0	0.092	12.2	0.427		
5.2	0.0698B	14.8	0.1178B	4.2	0.086	12.3	0.578		
5.5	0.0708B	15.0	0.1178B	4.5	0.078	12.36	0.653		
5.8	0.0718B			4.8	0.072	12.38	0.667		
6.0	0.0728B			5.0	0.068	12.40	0.675		
6.2	0.0738B			5.2	0.065	12.42	0.678		
6.5	0.0738B			5.5	0.061	12.46	0.680		
6.8	0.0728B			5.8	0.057	12.5	0.682		
7.0	0.0728B			6.0	0.055	12.54	0.681		
7.2	0.0728B			6.2	0.053	12.6	0.676		
7.5	0.0738B			6.5	0.051	12.64	0.661		
7.8	0.0748B			6.8	0.049	12.7	0.620		
8.0	0.0758B			7.0	0.048	12.8	0.524		
8.2	0.0778B			7.2	0.047	12.9	0.435		
8.5	0.0798B			7.5	0.046	13.0	0.360		
8.8	0.0818B			7.8	0.044	13.1	0.289		
9.0	0.0838B			8.0	0.044	13.2	0.227		
9.2	0.0858B			8.2	0.043	13.3	0.189		
9.5	0.0868B			8.5	0.038	13.5	0.147		
9.8	0.0848B			8.8	0.032	13.7	0.121		
10.0	0.0818B			9.0	0.027	13.8	0.112		
10.2	0.0798B			9.2	0.023	14.0	0.100		
10.5	0.0778B			9.5	0.017	14.2	0.092		

† VALUE FOLLOWED BY A "B" IS TYPICAL.

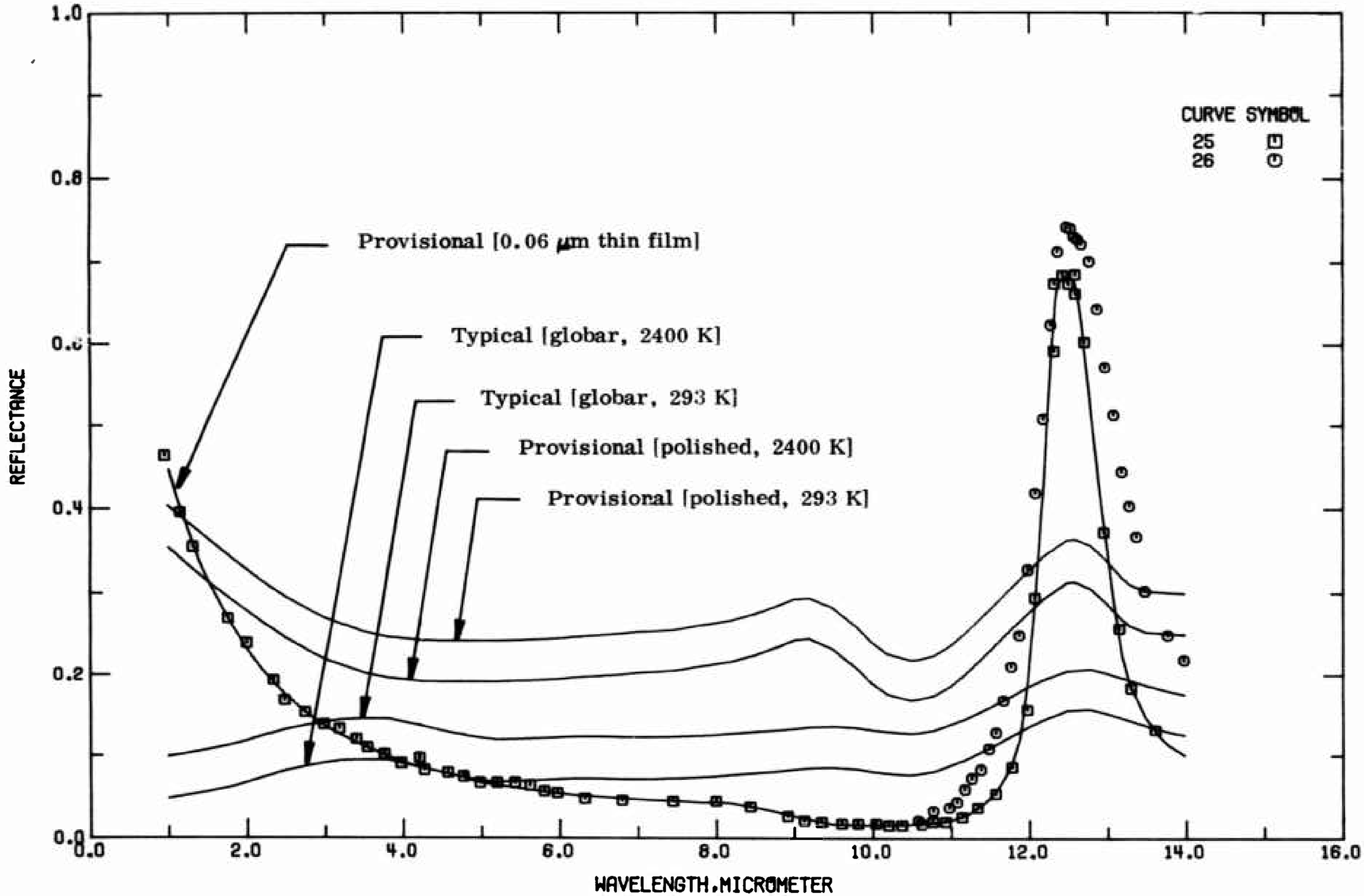


FIGURE 13-5. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE).

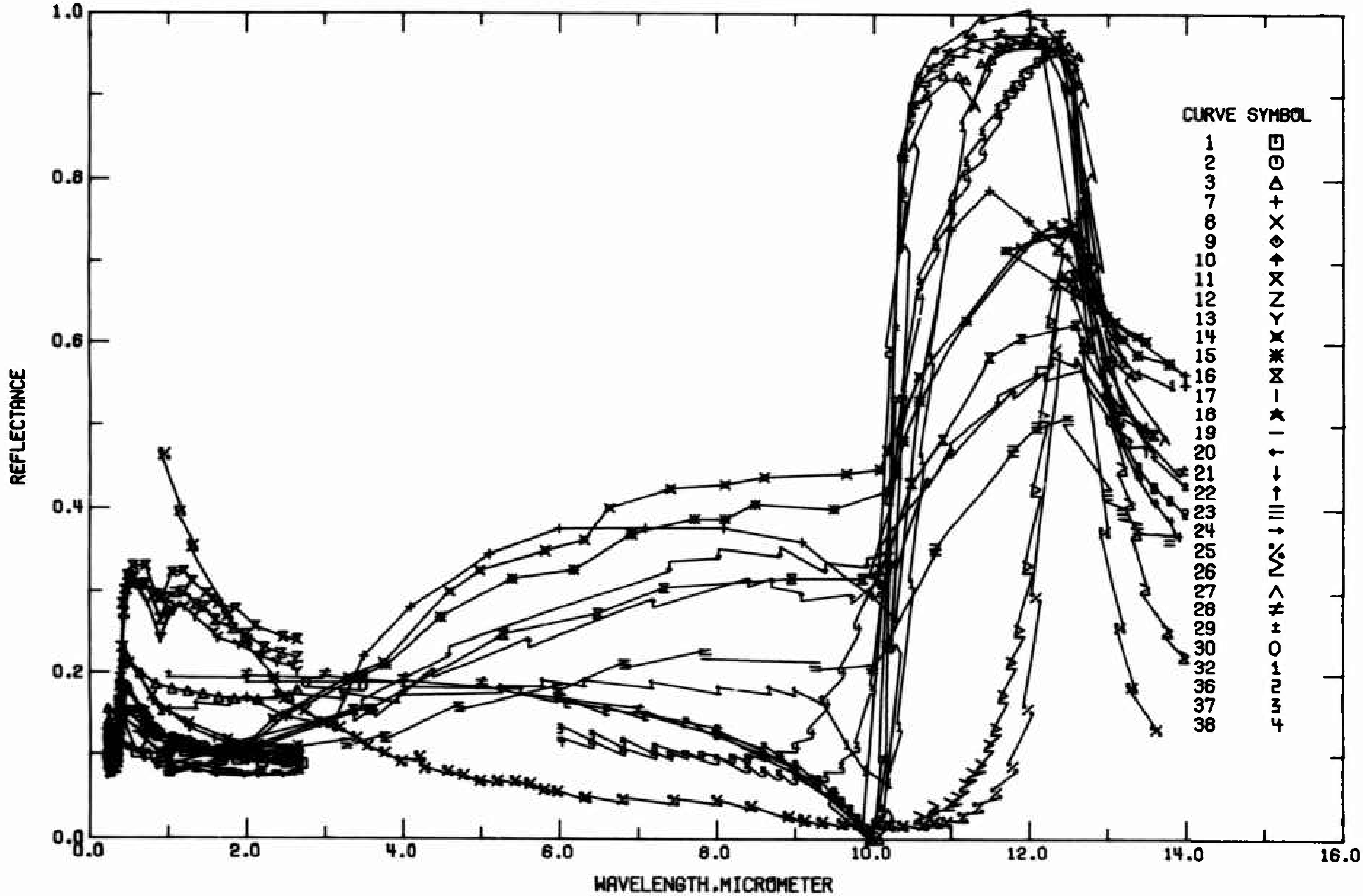


FIGURE 13-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE).

TABLE 13-8. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF SILICON MONOCARBIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T10060	Olson, O.H. and Morris, J.C.	1959	0.316-2.70	298		Magnesium carbonate reference standard; $\theta = 9°$, $\omega' = 2\pi$; reported error 4%.
2	T22272	Schatz, E.A., Goldberg, D.M., Pearson, E.G., and Burks, T.L.	1963	0.230-2.64	298	Sample No. 102	Commercially sintered sample from Carborundum; density 2.32 g cm^{-3}; theoretical density 3.21 g cm^{-3}; MgO reference standard; data extracted from smooth curve; $\theta = \sim 0°$, $\omega' = 2\pi$.
3	T22272	Schatz, E.A., et al.	1963	0.230-2.65	298	Sample No. 103	Sintered at 2173 K for 1 hr (setter material SiC); density 1.49 g cm^{-3}; theoretical density 3.21 g cm^{-3}; MgO reference standard; data extracted from smooth curve; $\theta = \sim 0°$, $\omega' = 2\pi$.
4	T40808	Imai, A.	1966	15.1-30.1	300	B-106	n-type; single crystal of hexagonal plate; grown in a Lely's type furnace from commercial grade or purified SiC; carrier density at 300 K 1.4 x 10^{19} cm^{-3}; measured in argon-nitrogen; incident beam perpendicular to the c-plane; $\theta = \sim 0°$, $\theta' = \sim 0°$.
5	T40808	Imai, A.	1966	14.5-32.5	300	B-93	Similar to the above specimen and conditions except carrier density at 300 K 3.9 x 10^{17} cm^{-3}.
6	T40808	Imai, A.	1966	14.0-31.1	300	B-97	Similar to the above specimen and conditions except 15 μm thick; carrier density at 300 K 1.2 x 10^{18} cm^{-3}.
7	T42979	Chang, L.	1965	2.00-29.9	~298		Polycrystalline (Carborundum Co.); $\theta = \sim 0°$, $\theta' = \sim 0°$.
8	T35840	Schatz, E.A., Alvarez, G.H., Counts, C.R., and Hoppke, M.A.	1965	0.230-2.65	~298		Black powder from Norton Co.; 98 pure; compacted at 70,500 psi; data extracted from smooth curve; MgO reference standard; $\theta = 0°$, $\omega' = 2\pi$.
9	T35840	Schatz, E.A., et al.	1965	0.230-2.65	~298		Similar to the above specimen and conditions except compacted at 35,250 psi.
10	T35840	Schatz, E.A., et al.	1965	0.230-2.65	~298		Similar to the above specimen and conditions except compacted at 11,750 psi.
11	T35840	Schatz, E.A., et al.	1965	0.230-2.65	~298		Green powder from Norton Co.; 99.4 pure; compacted at 70,500 psi; data extracted from smooth curve; MgO reference standard; $\theta = 0°$, $\omega' = 2\pi$.
12	T35840	Schatz, E.A., et al.	1965	0.230-2.65	~298		Similar to the above specimen and conditions except compacted at 35,250 psi.
13	T35840	Schatz, E.A., et al.	1965	0.230-2.65	~298		Similar to the above specimen and conditions except compacted at 11,750 psi.
14	T37398	Schatz, E.A., Counts, C.R., III, and Burks, T.L.	1964	1.00-15.0	~298		98.1 pure powder from Fisher Scientific Co.; mesh size 320; compacted at 1400 psi with highly polished stainless steel ram; data extracted from smooth curve; converted from reflectance factor; $\theta = 0°$, $\omega' = 2\pi$.
15	T37398	Schatz, E.A., et al.	1964	1.00-15.0	~298		Similar to the above specimen and conditions except compacted at 7000 psi; $\theta = \sim 0°$.
16	T37398	Schatz, E.A., et al.	1964	1.00-15.0	~298		Similar to the above specimen and conditions except compacted at 28,000 psi.
17	T37398	Schatz, E.A., et al.	1964	0.230-2.65	~298		98.1 pure powder (regular crystolon, Norton Co.); particle size 7 μm; compacted at 23,500 psi with highly polished stainless steel ram; data extracted from smooth curve; MgO reference standard; $\theta = 0°$, $\omega' = 2\pi$.
18	T37398	Schatz, E.A., et al.	1964	0.230-2.65	~298		Similar to the above specimen and conditions except particle size 30 μm; $\theta = \sim 0°$.
19	T37398	Schatz, E.A., et al.	1964	0.230-2.65	~298		Similar to the above specimen and conditions except particle size 70 μm.
20	T37398	Schatz, E.A., et al.	1964	0.230-2.65	~298		Similar to the above specimen and conditions except particle size 160 μm.
21	T37398	Schatz, E.A., et al.	1964	1.00-15.0	~298		98.1 pure powder (regular crystolon, Norton Co.); particle size 7 μm; compacted at 42,000 psi with highly polished stainless steel ram; data extracted from smooth curve; converted from reflectance factor; $\theta = 0°$, $\omega' = 2\pi$.

TABLE 13-8. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF SILICON MONOCARBIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
22	T37398	Schatz, E.A., Counts, C.R., III, and Burks, T.L.	1964	1.00-15.0	~298		Similar to the above specimen and conditions except particle size 30 μm; $\theta = \sim 0°$.
23	T37398	Schatz, E.A., et al.	1964	1.00-15.0	~298		Similar to the above specimen and conditions except particle size 70 μm.
24	T37398	Schatz, E.A., et al.	1964	0.230-2.65	~298		98.1 pure powder, Norton Co.; mesh size 400; compacted with highly polished stainless steel ram; data extracted from smooth curve; MgO reference standard; $\theta = 0°$, $\omega' = 2\pi$.
25	T32822 E17420	Spitzer, W.G., Kleinman, D.A., and Frosch, C.J.	1959	0.95-14	293		β-phase polycrystalline cubic SiC film 0.06 μm thick; measured by comparing reflected energy from the specimen with that from a good-quality front-surface aluminum mirror; $\theta = 0°$.
26	T32822 E17420	Spitzer, W.G., et al.	1959	11-14	293		Similar to the above except specimen thickness 0.12 μm.
27	T32821 E17420	Spitzer, W.G., Kleinman, D., and Walsh, D.	1959	8.0-15	293		α-II hexagonal; about 3 mm high and larger than 25 mm^2 in basal area; supplied by Exolon Corp.; surface polished, oxidized at 1273 K for 2 hr, then washed by HF; measured for extraordinary ray with electric vector polarized parallel to optic axis (lying in surface); $\theta = \sim 0°$.
28	T32821 E17420	Spitzer, W.G., et al.	1959	2.0-22	293		The above specimen measured for ordinary ray with electric vector polarized perpendicular to optic axis.
29	E3607	Lely, J.A. and Kröger, F.A.	1958	1.0-15	293		Hexagonal; colorless; single crystal; measured with unpolarized light normal to a plane perpendicular to c-axis; data taken from smooth curve; $\theta = 0°$.
30	E17415	Lipson, H.G.	1960	2.77,3.5	293		α-II hexagonal; values calculated from measured transmittance.
31	E17419	Philipp, H.R. and Taft, E.A.	1960	0.11-1.2	300		Type 6H hexagonal; data measured by using a vacuum grating monochrometer.
32	T22517	Coblentz, W.W.	1906	0.90-14	293	Carborundum	No details reported.
33	T43162	Wheeler, B.E.	1966	0.096-0.41	293		6H hexagonal single crystal; data taken from smooth curve
34	T43162	Wheeler, B.E.	1966	0.096-0.41	293		β-phase cubic single crystal; data taken from smooth curve.
35	T72608	Purtseladze, I.M. and Khavtasi, L.G.	1971	0.18-2.5	300		Type 27R; α-phase; nitrogen doped; 150 to 200 μ thick; mechanically ground and polished; difference between donor and acceptor concentrations $N_D - N_A = 2 \times 10^{17}$ cm^{-3}.
36	T64949	Il'in, M.A., Kukharskii, A.A., Rashevskaya, E.P., and Subashiev, V.K.	1971	6.1-44	293	1	6H hexagonal single crystal; prepared by recrystallization; electrical conductivity 20 to 25 Ω^{-1} cm^{-1}; carrier concentration 1.1×10^{17} cm^{-3}.
37	T64949	Il'in, M.A., et al.	1971	6.0-44	293	4	Similar to the above specimen except electrical conductivity 66 to 71 Ω^{-1} cm^{-1} and carrier concentration 6.8×10^{18} cm^{-3}.
38	T64949	Il'in, M.A., et al.	1971	6.0-44	293	6	Similar to the above specimen except electrical conductivity 100 to 105 Ω^{-1} cm^{-1} and carrier concentration 1.36×10^{19} cm^{-3}.

TABLE 13-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 298.	
0.316	0.147
0.397	0.149
0.600	0.130
0.921	0.100
1.00	0.102
1.22	0.102
1.35	0.108
1.70	0.097
1.89	0.093
2.20	0.089
2.41	0.093
2.51	0.089
2.71	0.068
CURVE 2	
T = 298.	
0.230	0.395
0.240	0.090
0.250	0.088
0.260	0.089
0.280	0.090
0.290	0.093
0.320	0.099
0.330	0.104
0.340	0.105
0.350	0.111
0.410	0.148
0.493	0.152
0.613	0.150
0.751	0.134
0.850	0.121
1.05	0.119
1.15	0.115
1.25	0.114
1.45	0.108
1.65	0.104
1.85	0.102
2.15	0.100

λ	ρ
CURVE 2 (CONT.)	
2.45	0.100
2.55	0.103
2.65	0.103
CURVE 3	
T = 298.	
0.230	0.155
0.240	0.140
0.250	0.130
0.270	0.117
0.290	0.106
0.310	0.100
0.320	0.094
0.340	0.094
0.350	0.095
0.379	0.128
0.425	0.209
0.460	0.220
0.648	0.198
0.848	0.185
1.05	0.179
1.25	0.176
1.45	0.173
1.65	0.169
1.85	0.167
2.15	0.166
2.55	0.170
2.65	0.178
CURVE 4*	
T = 300.	
15.1	0.404
16.0	0.397
17.1	0.397
18.0	0.398
19.0	0.396
20.1	0.396
21.0	0.397

λ	ρ
CURVE 4 (CONT.)*	
22.0	0.405
23.0	0.412
24.0	0.431
25.0	0.450
26.0	0.445
27.0	0.443
28.0	0.466
29.1	0.466
30.1	0.466
CURVE 5*	
T = 300.	
14.5	0.400
15.0	0.380
15.5	0.375
16.0	0.347
16.5	0.342
17.0	0.332
17.6	0.326
18.0	0.320
18.5	0.317
19.0	0.313
19.4	0.311
20.0	0.310
20.5	0.306
21.0	0.303
21.5	0.300
22.0	0.295
22.5	0.300
23.0	0.294
23.5	0.292
24.0	0.292
24.5	0.295
25.0	0.293
25.5	0.294
26.0	0.293
26.5	0.291
27.0	0.293
27.5	0.298

λ	ρ
CURVE 5 (CONT.)*	
28.0	0.304
28.5	0.300
29.0	0.293
29.5	0.291
30.0	0.292
30.5	0.291
31.0	0.291
31.5	0.291
32.0	0.291
32.5	0.291
CURVE 6*	
T = 300.	
14.0	0.440
14.5	0.400
15.0	0.390
15.5	0.375
16.0	0.361
17.0	0.338
18.0	0.333
19.0	0.327
20.0	0.332
21.0	0.332
22.0	0.327
23.0	0.327
24.0	0.327
25.0	0.327
26.0	0.329
27.0	0.333
28.0	0.342
29.0	0.336
30.0	0.332
31.1	0.334
CURVE 7	
T = 298.	
2.00	0.169
2.50	0.145

λ	ρ
CURVE 7 (CONT.)	
3.10	0.134
3.50	0.221
4.10	0.279
5.10	0.345
6.00	0.374
7.10	0.375
8.10	0.375
9.10	0.359
10.0	0.295
10.3	0.266
10.6	0.536
11.0	0.739
11.5	0.786
12.0	0.750
12.5	0.706
13.0	0.631
14.0	0.562
14.0	0.550
15.0	0.530
16.0	0.520
18.0	0.497
19.9	0.488
22.0	0.488
24.0	0.488
26.0	0.488
27.9	0.489
29.9	0.491
CURVE 8	
T = 298.	
0.230	0.107
0.253	0.092
0.288	0.089
0.323	0.093
0.350	0.115
0.395	0.193
0.425	0.209
0.443	0.212
0.499	0.212

λ	ρ
CURVE 8 (CONT.)	
0.796	0.171
0.964	0.154
1.25	0.138
1.76	0.118
2.14	0.111
2.65	0.110
CURVE 9	
T = 298.	
0.230	0.104
0.252	0.090
0.284	0.086
0.330	0.091
0.347	0.096
0.350	0.108
0.394	0.168
0.427	0.181
0.466	0.181
0.701	0.147
0.840	0.131
1.04	0.117
1.28	0.110
1.46	0.102
2.00	0.092
2.65	0.090
CURVE 10	
T = 298.	
0.230	0.101
0.261	0.086
0.280	0.083
0.328	0.084
0.340	0.089
0.348	0.093
0.350	0.105
0.401	0.157
0.688	0.133
0.805	0.121

*NOT SHOWN IN FIGURE.

TABLE 13-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 10 (CONT.)	
1.03	0.108
1.31	0.100
1.74	0.093
2.65	0.086
CURVE 11	
T = 298.	
0.230	0.131
0.239	0.120
0.248	0.111
0.280	0.103
0.311	0.100
0.331	0.106
0.346	0.118
0.349	0.123
0.378	0.165
0.428	0.283
0.450	0.301
0.491	0.319
0.548	0.331
0.710	0.331
0.850	0.295
0.883	0.289
0.915	0.289
1.05	0.323
1.20	0.324
1.31	0.312
1.49	0.296
1.571	0.288
1.64	0.282
1.87	0.277
2.12	0.256
2.47	0.243
2.65	0.240
CURVE 12	
T = 298.	
0.230	0.125
CURVE 12 (CONT.)	
0.240	0.115
0.249	0.105
0.268	0.099
0.294	0.097
0.319	0.101
0.337	0.110
0.348	0.117
0.353	0.130
0.378	0.160
0.408	0.231
0.432	0.271
0.471	0.300
0.515	0.314
0.561	0.317
0.643	0.307
0.716	0.309
0.910	0.264
1.00	0.290
1.10	0.297
1.21	0.299
1.35	0.282
1.46	0.279
1.60	0.263
1.83	0.253
2.00	0.246
2.23	0.231
2.44	0.224
2.65	0.219
CURVE 13	
T = 298.	
0.230	0.114
0.240	0.103
0.251	0.095
0.274	0.094
0.288	0.092
0.313	0.096
0.331	0.102
0.348	0.112
CURVE 13 (CONT.)	
0.356	0.122
0.380	0.141
0.416	0.232
0.438	0.263
0.495	0.300
0.532	0.309
0.565	0.309
0.649	0.299
0.733	0.285
0.899	0.241
1.01	0.270
1.04	0.274
1.07	0.274
1.10	0.279
1.21	0.279
1.34	0.267
1.58	0.248
1.63	0.242
1.90	0.234
2.19	0.220
2.39	0.212
2.59	0.208
2.65	0.201
CURVE 14	
T = 298.	
1.00	0.107
1.97	0.107
2.33	0.142
3.30	0.193
3.75	0.213
4.60	0.299
4.98	0.326
5.82	0.349
6.32	0.361
6.64	0.400
7.42	0.424
8.12	0.429
8.62	0.438
CURVE 14 (CONT.)	
9.67	0.442
10.1	0.447
10.2	0.468
10.6	0.560
11.9	0.718
12.3	0.745
12.5	0.738
12.7	0.700
12.9	0.655
13.1	0.627
13.4	0.608
13.5	0.602
15.0	0.597
CURVE 15	
T = 298.	
1.00	0.104
1.97	0.104
2.50	0.147
3.48	0.195
3.78	0.209
4.48	0.267
5.39	0.316
6.18	0.327
6.92	0.368
7.73	0.386
8.12	0.386
8.50	0.405
9.51	0.399
10.2	0.422
10.3	0.443
10.4	0.480
10.6	0.530
11.2	0.628
12.1	0.732
12.4	0.735
12.7	0.714
13.0	0.635
13.2	0.604
CURVE 15 (CONT.)	
13.4	0.585
13.8	0.575
14.5	0.569
15.0	0.565
CURVE 16	
T = 298.	
1.00	0.079
1.36	0.083
3.36	0.154
3.57	0.154
5.28	0.247
6.49	0.272
7.33	0.305
8.97	0.317
9.88	0.317
10.1	0.323
10.2	0.342
10.5	0.431
10.9	0.482
11.5	0.582
11.9	0.605
12.6	0.623
12.7	0.593
13.0	0.545
13.2	0.519
13.6	0.488
15.0	0.484
CURVE 17	
T = 298.	
0.230	0.147
0.241	0.122
0.258	0.110
0.270	0.110
0.276	0.107
0.298	0.103
0.319	0.103
CURVE 17 (CONT.)	
0.327	0.109
0.336	0.113
0.338	0.119
0.349	0.119
0.350	0.154
0.391	0.202
0.399	0.228
0.444	0.228
0.806	0.164
0.912	0.154
1.01	0.151
1.26	0.132
1.58	0.119
1.81	0.111
2.18	0.107
2.65	0.109
CURVE 18	
T = 298.	
0.230	0.127
0.249	0.103
0.298	0.101
0.330	0.103
0.332	0.108
0.349	0.112
0.350	0.133
0.395	0.182
0.424	0.185
0.472	0.182
0.624	0.155
0.687	0.153
0.750	0.141
0.881	0.126
1.04	0.118
1.17	0.116
1.25	0.111
1.33	0.111
1.40	0.107
1.65	0.102

TABLE 13-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 18(CONT.)	
2.15	0.099
2.65	0.099
CURVE 19	
T = 298.	
0.230	0.117
0.241	0.101
0.246	0.101
0.251	0.094
0.298	0.096
0.305	0.102
0.343	0.102
0.348	0.106
0.369	0.123
0.385	0.140
0.410	0.147
0.609	0.127
0.679	0.124
0.689	0.122
0.702	0.104
0.834	0.092
0.950	0.090
0.997	0.090
1.05	0.083
1.16	0.090
1.25	0.082
1.70	0.080
1.72	0.076
1.75	0.081
1.79	0.076
1.80	0.081
1.88	0.079
1.90	0.074
2.00	0.077
2.13	0.076
2.17	0.080
2.22	0.074
2.35	0.074
2.38	0.079

λ	ρ
CURVE 19(CONT.)	
2.45	0.074
2.58	0.077
2.65	0.080
CURVE 20	
T = 298.	
0.230	0.094
0.236	0.082
0.246	0.080
0.258	0.072
0.275	0.078
0.287	0.076
0.324	0.077
0.330	0.083
0.348	0.083
0.350	0.097
0.397	0.111
0.463	0.111
0.520	0.106
0.674	0.103
0.721	0.093
0.863	0.089
0.893	0.083
1.28	0.082
1.59	0.077
1.65	0.074
2.00	0.073
2.04	0.075
2.16	0.075
2.18	0.073
2.50	0.074
2.61	0.077
2.65	0.076
CURVE 21	
T = 298.	
1.00	0.098
1.60	0.101

λ	ρ
CURVE 21(CONT.)	
3.47	0.160
4.58	0.226
7.40	0.331
8.03	0.346
8.82	0.348
9.40	0.330
9.93	0.336
10.1	0.349
11.0	0.472
11.6	0.532
12.1	0.566
12.3	0.577
12.6	0.577
13.2	0.503
13.5	0.497
15.0	0.499
CURVE 22	
T = 298.	
1.00	0.091
1.80	0.100
3.37	0.145
3.64	0.150
4.38	0.199
5.60	0.237
7.19	0.285
8.41	0.312
8.71	0.312
9.09	0.294
9.74	0.291
10.1	0.311
10.3	0.334
10.7	0.432
11.0	0.466
11.8	0.539
12.2	0.560
12.7	0.563
13.0	0.507
13.3	0.478

λ	ρ
CURVE 22(CONT.)	
13.5	0.469
14.7	0.460
15.0	0.460
CURVE 23	
T = 298.	
1.00	0.078
1.65	0.086
1.94	0.103
3.27	0.112
3.77	0.120
4.71	0.158
5.98	0.180
6.82	0.211
7.86	0.224
9.27	0.209
10.0	0.206
10.2	0.234
10.8	0.351
11.8	0.469
12.1	0.497
12.5	0.506
13.0	0.418
13.2	0.394
13.4	0.376
13.8	0.362
15.0	0.362
CURVE 24	
T = 298.	
0.230	0.132
0.250	0.105
0.265	0.098
0.290	0.095
0.330	0.100
0.337	0.102
0.339	0.105
0.350	0.108

λ	ρ
CURVE 24(CONT.)	
0.400	0.180
0.424	0.182
0.480	0.179
0.650	0.154
0.703	0.148
0.707	0.141
0.851	0.125
1.02	0.114
1.19	0.112
1.23	0.108
1.41	0.103
1.75	0.100
2.22	0.098
2.59	0.099
2.65	0.102
CURVE 25	
T = 293.	
0.95	0.464
1.15	0.395
1.31	0.354
1.76	0.269
2.00	0.239
2.34	0.193
2.48	0.168
2.74	0.153
2.98	0.138
3.18	0.133
3.40	0.120
3.54	0.110
3.76	0.102
3.97	0.091
4.21	0.097
4.27	0.083
4.57	0.080
4.77	0.075
4.98	0.068
5.20	0.068
5.43	0.068

λ	ρ
CURVE 25(CONT.)	
5.62	0.065
5.80	0.058
5.97	0.056
6.32	0.049
6.80	0.047
7.45	0.046
8.00	0.046
8.44	0.039
8.92	0.027
9.13	0.022
9.35	0.020
9.61	0.018
9.82	0.018
10.05	0.018
10.21	0.016
10.38	0.016
10.64	0.017
10.78	0.020
10.94	0.020
11.15	0.026
11.35	0.038
11.58	0.055
11.79	0.086
11.99	0.156
12.09	0.294
12.34	0.591
12.34	0.673
12.45	0.683
12.52	0.673
12.61	0.684
12.61	0.661
12.73	0.602
12.97	0.371
13.17	0.256
13.32	0.183
13.63	0.131

TABLE 13-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ
CURVE 26	
T = 293.	
10.59	0.022
10.78	0.034
10.98	0.038
11.08	0.045
11.18	0.060
11.27	0.073
11.39	0.083
11.49	0.108
11.58	0.128
11.68	0.168
11.78	0.210
11.88	0.248
11.99	0.327
12.09	0.419
12.19	0.507
12.29	0.623
12.38	0.712
12.49	0.742
12.54	0.741
12.59	0.730
12.63	0.727
12.68	0.721
12.78	0.700
12.88	0.642
12.98	0.571
13.09	0.512
13.19	0.445
13.29	0.403
13.38	0.366
13.49	0.302
13.78	0.248
13.99	0.218
CURVE 27	
T = 293.	
7.99	0.132
9.00	0.088
9.49	0.047

λ	ρ
CURVE 27(CONT.)	
9.96	0.0
10.07	0.0
10.19	0.031
10.30	0.231
10.41	0.716
10.52	0.839
10.69	0.895
10.90	0.925
11.09	0.925
11.19	0.919
11.31	0.885
11.38	0.940
11.51	0.946
11.61	0.959
11.72	0.961
11.93	0.964
12.13	0.964
12.32	0.964
12.51	0.961
12.63	0.949
12.70	0.891
12.80	0.802
12.89	0.692
13.08	0.607
13.21	0.578
13.30	0.561
13.74	0.482
14.47	0.401
15.00	0.379
CURVE 28	
T = 293.	
2.00	0.198
3.00	0.198
4.00	0.193
5.00	0.188
6.00	0.170
7.00	0.156
8.00	0.131

λ	ρ
CURVE 28(CONT.)	
8.98	0.086
9.49	0.053
9.99	0.011
10.09	0.024
10.14	0.095
10.31	0.533
10.38	0.825
10.53	0.887
10.60	0.914
10.75	0.934
10.97	0.953
11.26	0.970
11.62	0.976
12.04	0.978
12.40	0.975
12.62	0.912
12.66	0.758
12.82	0.664
13.04	0.580
13.51	0.489
13.96	0.446
14.48	0.415
16.00	0.358
19.01	0.324
22.00	0.303
CURVE 29	
T = 293.	
1.0	0.196
2.0	0.190
4.0	0.185
5.5	0.178
7.0	0.155
8.0	0.131
8.6	0.106
9.0	0.086
9.3	0.064
9.6	0.042
10.0	0.000

λ	ρ
CURVE 29(CONT.)	
10.1	0.037
10.2	0.085
10.3	0.619
10.4	0.786
10.5	0.886
10.6	0.925
10.8	0.956
11.2	0.975
11.4	0.991
12.0	1.000
12.2	0.989
12.4	0.966
12.6	0.936
12.7	0.781
12.8	0.706
12.9	0.651
13.0	0.619
13.1	0.576
13.2	0.529
13.4	0.500
13.6	0.466
14.0	0.428
14.3	0.386
15.0	0.322
15.4	0.271
CURVE 30	
T = 293.	
2.77	0.187
3.5	0.183
CURVE 31*	
T = 300.	
0.110	0.338
0.113	0.360
0.115	0.371
0.117	0.380
0.119	0.387

λ	ρ
CURVE 31(CONT.)*	
0.121	0.393
0.123	0.393
0.126	0.399
0.129	0.404
0.131	0.409
0.134	0.415
0.138	0.422
0.140	0.432
0.144	0.450
0.147	0.473
0.149	0.493
0.150	0.505
0.152	0.522
0.154	0.531
0.156	0.536
0.158	0.540
0.160	0.541
0.162	0.541
0.166	0.535
0.172	0.526
0.176	0.515
0.181	0.495
0.187	0.470
0.193	0.442
0.199	0.417
0.207	0.389
0.213	0.360
0.219	0.336
0.229	0.316
0.238	0.299
0.248	0.287
0.257	0.276
0.268	0.257
0.281	0.259
0.294	0.253
0.310	0.245
0.325	0.240
0.345	0.235
0.363	0.229
0.389	0.224

λ	ρ
CURVE 31(CONT.)*	
0.413	0.219
0.443	0.215
0.475	0.213
0.514	0.209
0.564	0.207
0.620	0.202
0.713	0.202
0.838	0.199
0.984	0.199
1.24	0.199
CURVE 32	
T = 293.	
0.90	0.153
1.35	0.160
1.77	0.164
2.37	0.173
3.22	0.173
3.93	0.169
5.24	0.181
5.78	0.189
6.31	0.189
7.17	0.187
8.03	0.180
8.68	0.180
9.00	0.178
9.36	0.168
9.67	0.114
9.91	0.082
10.21	0.067
10.34	0.136
10.50	0.312
10.63	0.460
10.75	0.581
11.15	0.863
11.49	0.938
11.71	0.969
12.00	0.969
12.24	0.958

*NOT SHOWN IN FIGURE.

TABLE 13-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 32(CONT.)	
12.45	0.912
12.75	0.786
12.96	0.629
13.23	0.578
13.41	0.564
13.84	0.551
14.34	0.534
CURVE 33*	
T = 293.	
0.0963	0.501
0.100	0.517
0.104	0.537
0.109	0.562
0.114	0.587
0.115	0.598
0.119	0.626
0.121	0.646
0.125	0.661
0.128	0.673
0.129	0.673
0.132	0.668
0.133	0.656
0.135	0.642
0.138	0.642
0.141	0.648
0.143	0.659
0.145	0.674
0.147	0.701
0.149	0.728
0.152	0.746
0.156	0.773
0.159	0.795
0.162	0.789
0.164	0.770
0.166	0.742
0.170	0.718
0.175	0.723
0.178	0.713

λ	ρ
CURVE 33(CONT.)*	
0.182	0.722
0.185	0.722
0.190	0.716
0.197	0.684
0.206	0.640
0.215	0.609
0.223	0.597
0.225	0.589
0.231	0.577
0.236	0.557
0.243	0.543
0.252	0.532
0.261	0.526
0.270	0.520
0.276	0.520
0.284	0.508
0.301	0.501
0.331	0.488
0.369	0.478
0.413	0.469
CURVE 34*	
T = 293.	
0.0963	0.288
0.103	0.303
0.109	0.323
0.113	0.334
0.117	0.358
0.120	0.377
0.123	0.396
0.126	0.411
0.128	0.411
0.130	0.405
0.132	0.394
0.134	0.380
0.135	0.358
0.137	0.343
0.139	0.343
0.141	0.354

λ	ρ
CURVE 34(CONT.)*	
0.142	0.392
0.147	0.461
0.148	0.482
0.149	0.510
0.152	0.536
0.155	0.553
0.158	0.572
0.160	0.589
0.162	0.583
0.163	0.563
0.165	0.553
0.168	0.542
0.172	0.537
0.175	0.533
0.178	0.525
0.186	0.496
0.198	0.457
0.204	0.448
0.207	0.451
0.209	0.451
0.213	0.439
0.217	0.417
0.220	0.400
0.225	0.380
0.232	0.361
0.240	0.338
0.248	0.324
0.257	0.313
0.270	0.313
0.282	0.305
0.302	0.294
0.343	0.284
0.413	0.267
CURVE 35*	
T = 300.	
0.18	0.219
0.26	0.213
0.34	0.213

λ	ρ
CURVE 35(CONT.)*	
0.40	0.200
0.49	0.186
0.58	0.171
0.69	0.148
0.80	0.133
0.91	0.113
0.99	0.065
0.99	0.192
1.02	0.440
1.03	0.702
1.06	0.821
1.06	0.883
1.10	0.914
1.14	0.914
1.19	0.825
1.19	0.714
1.23	0.619
1.29	0.529
1.45	0.411
1.56	0.360
1.66	0.329
1.93	0.308
2.06	0.308
2.14	0.308
2.22	0.308
2.28	0.316
2.45	0.316
2.52	0.304
CURVE 36	
T = 293.	
6.1	0.163
6.6	0.154
7.1	0.148
7.6	0.140
8.0	0.126
8.6	0.110
9.0	0.088
9.3	0.070

λ	ρ
CURVE 36(CONT.)	
9.5	0.056
9.6	0.044
9.7	0.035
9.8	0.024
9.9	0.012
10.1	0.003
10.2	0.589
10.4	0.779
10.4	0.837
10.5	0.873
10.7	0.911
10.9	0.935
11.0	0.945
11.2	0.954
11.4	0.960
11.6	0.960
11.8	0.964
12.0	0.964
12.2	0.964
12.5	0.940
12.6	0.914
12.8	0.663
13.0	0.542
13.2	0.485
13.4	0.450
13.6	0.427
13.8	0.412
14.0	0.395
15.0	0.350
15.9	0.315
18.0	0.305
20.0	0.296
21.9	0.289
24.1	0.278
26.0	0.274
28.2	0.267
30.1	0.262
32.0	0.261
34.2	0.259
36.2	0.260

λ	ρ
CURVE 36(CONT.)	
38.0	0.259
40.1	0.260
42.1	0.260
44.1	0.260
CURVE 37	
T = 293.	
6.0	0.132
6.4	0.125
6.8	0.116
7.2	0.109
8.0	0.095
8.4	0.085
8.6	0.080
8.8	0.076
9.0	0.071
9.2	0.071
9.4	0.074
9.6	0.085
9.8	0.110
10.0	0.180
10.2	0.329
10.4	0.538
10.6	0.673
10.8	0.723
11.0	0.769
11.2	0.817
11.4	0.853
11.6	0.882
11.7	0.900
11.8	0.912
11.9	0.925
12.2	0.950
12.7	0.679
12.8	0.594
15.0	0.328
16.0	0.303
17.0	0.286
18.1	0.286

*NOT SHOWN IN FIGURE.

TABLE 13-9. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ
CURVE 37 (CONT.)		CURVE 38 (CONT.)	
18.9	0.286	11.2	0.799
20.1	0.288	11.4	0.830
22.0	0.298	11.6	0.872
23.9	0.303	11.7	0.890
26.1	0.316	11.8	0.904
28.0	0.327	11.9	0.913
30.2	0.346	12.0	0.929
32.1	0.363	12.1	0.942
34.1	0.380	12.3	0.955
36.2	0.398	12.4	0.960
38.0	0.419	12.5	0.906
40.1	0.441	12.7	0.693
42.0	0.460	12.8	0.616
43.9	0.475	13.0	0.530
		13.2	0.476
CURVE 38		13.4	0.438
T = 293.		13.6	0.409
		13.8	0.386
6.0	0.116	13.9	0.367
6.4	0.113	15.0	0.345
6.8	0.104	15.9	0.327
7.2	0.100	17.0	0.300
7.4	0.099	18.1	0.297
7.6	0.100	20.0	0.322
7.8	0.099	22.1	0.352
8.2	0.096	24.1	0.377
8.4	0.096	26.1	0.408
8.6	0.099	28.1	0.432
8.8	0.099	30.1	0.457
9.0	0.109	32.1	0.473
9.2	0.127	34.1	0.496
9.4	0.163	36.0	0.513
9.6	0.201	38.1	0.529
9.8	0.255	40.0	0.550
10.0	0.319	41.9	0.562
10.2	0.406	44.1	0.579
10.4	0.523		
10.6	0.656		
10.8	0.715		
11.0	0.759		

d. Normal Spectral Absorptance (Wavelength Dependence)

Only four sets of data are available. Three of them were measured below 1 μm. The remaining one [T32388] was measured between 0.4 and 2.6 μm for Globar without any detailed description about the specimen.

It is impossible to generate recommended curves from the meager experimental data. However, it is adequate to apply Kirchhoff's law on the Globar and the averagely polished silicon carbide. Hence, the recommended values presented in subsection (a) are repeated here as recommended values for the normal spectral absorptance. The uncertainty of each curve is believed to be the same as that of the emittance.

The recommended and the provisional curves are shown in Figure 13-7 and the experimental curves are shown in Figure 13-8. The recommended and the provisional values, the experimental measurement information, and the experimental data are tabulated in Tables 13-10, 13-11, and 13-12, respectively.

TABLE 13-10. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α	λ	α	λ	α	λ	α
GLOBAR,BULK OXICIZED T = 293		GLOBAR,BULK OXIDIZED T = 293 (CONT.)		GLOBAR,BULK OXIDIZED T = 1400		GLOBAR,BULK OXIDIZED T = 1400 (CONT.)		GLOBAR,BULK OXIDIZED T = 2400		GLOBAR,BULK OXIDIZED T = 2400 (CONT.)	
1.0	0.901	10.6	0.872	1.0	0.928	10.6	0.899	1.0	0.951	10.6	0.922
1.2	0.899	10.8	0.869	1.2	0.925	10.8	0.896	1.2	0.948	10.8	0.919
1.5	0.893	11.0	0.862	1.5	0.920	11.0	0.889	1.5	0.943	11.0	0.912
1.8	0.887	11.2	0.855	1.8	0.914	11.2	0.882	1.8	0.937	11.2	0.905
2.0	0.882	11.5	0.841	2.0	0.909	11.5	0.868	2.0	0.932	11.5	0.891
2.2	0.876	11.8	0.826	2.2	0.903	11.8	0.853	2.2	0.926	11.8	0.876
2.5	0.868	12.0	0.815	2.5	0.895	12.0	0.842	2.5	0.918	12.0	0.865
2.8	0.862	12.2	0.806	2.8	0.889	12.2	0.833	2.8	0.912	12.2	0.856
3.0	0.859	12.5	0.795	3.0	0.886	12.5	0.822	3.0	0.909	12.5	0.845
3.2	0.856	12.8	0.793	3.2	0.883	12.8	0.820	3.2	0.906	12.8	0.843
3.5	0.855	13.0	0.798	3.5	0.882	13.0	0.825	3.5	0.905	13.0	0.848
3.8	0.855	13.2	0.804	3.8	0.882	13.2	0.831	3.8	0.905	13.2	0.854
4.0	0.859	13.5	0.813	4.0	0.886	13.5	0.840	4.0	0.909	13.5	0.863
4.2	0.863	13.8	0.821	4.2	0.890	13.8	0.848	4.2	0.913	13.8	0.871
4.5	0.870	14.0	0.825	4.5	0.897	14.0	0.852	4.5	0.920	14.0	0.875
4.8	0.876	14.2	0.829	4.8	0.903	14.2	0.856	4.8	0.926	14.2	0.879
5.0	0.879	14.5	0.831	5.0	0.906	14.5	0.858	5.0	0.929	14.5	0.881
5.2	0.881	14.8	0.833	5.2	0.908	14.8	0.860	5.2	0.931	14.8	0.883
5.5	0.880	15.0	0.833	5.5	0.907	15.0	0.860	5.5	0.930	15.0	0.883
5.8	0.879			5.8	0.906			5.8	0.929		
6.0	0.878			6.0	0.905			6.0	0.928		
6.2	0.877			6.2	0.904			6.2	0.927		
6.5	0.877			6.5	0.904			6.5	0.927		
6.8	0.878			6.8	0.905			6.8	0.928		
7.0	0.878			7.0	0.905			7.0	0.928		
7.2	0.878			7.2	0.905			7.2	0.928		
7.5	0.877			7.5	0.904			7.5	0.927		
7.8	0.876			7.8	0.903			7.8	0.926		
8.0	0.875			8.0	0.902			8.0	0.925		
8.2	0.873			8.2	0.900			8.2	0.923		
8.5	0.871			8.5	0.898			8.5	0.921		
8.8	0.869			8.8	0.896			8.8	0.919		
9.0	0.867			9.0	0.894			9.0	0.917		
9.2	0.865			9.2	0.892			9.2	0.915		
9.5	0.864			9.5	0.891			9.5	0.914		
9.8	0.866			9.8	0.893			9.8	0.916		
10.0	0.869			10.0	0.896			10.0	0.919		
10.2	0.871			10.2	0.898			10.2	0.921		
10.5	0.873			10.5	0.900			10.5	0.923		

TABLE 13-10. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α	λ	α	λ	α	λ	α
BULK POLISHED T = 293		BULK POLISHED T = 293 (CONT.)		BULK POLISHED T = 1000		BULK POLISHED T = 1000 (CONT.)		BULK POLISHED T = 2400		BULK POLISHED T = 2400 (CONT.)	
1.0	0.597A†	10.6	0.781A†	1.0	0.614A†	10.6	0.798A†	1.0	0.647A†	10.6	0.831A†
1.2	0.613A	10.8	0.776A	1.2	0.630A	10.8	0.793A	1.2	0.663A	10.8	0.826A
1.5	0.636A	11.0	0.765A	1.5	0.653A	11.0	0.782A	1.5	0.686A	11.0	0.815A
1.8	0.658A	11.2	0.749A	1.8	0.675A	11.2	0.766A	1.8	0.708A	11.2	0.799A
2.0	0.672A	11.5	0.721A	2.0	0.689A	11.5	0.738A	2.0	0.722A	11.5	0.771A
2.2	0.686A	11.8	0.693A	2.2	0.703A	11.8	0.710A	2.2	0.736A	11.8	0.743A
2.5	0.705A	12.0	0.675A	2.5	0.722A	12.0	0.692A	2.5	0.755A	12.0	0.725A
2.8	0.721A	12.2	0.657A	2.8	0.738A	12.2	0.674A	2.8	0.771A	12.2	0.707A
3.0	0.731A	12.5	0.638A	3.0	0.748A	12.5	0.655A	3.0	0.781A	12.5	0.688A
3.2	0.738A	12.6	0.637A	3.2	0.755A	12.6	0.654A	3.2	0.788A	12.6	0.687A
3.5	0.748A	12.8	0.645A	3.5	0.765A	12.8	0.662A	3.5	0.798A	12.8	0.695A
3.8	0.754A	13.0	0.662A	3.8	0.771A	13.0	0.679A	3.8	0.804A	13.0	0.712A
4.0	0.756A	13.2	0.682A	4.0	0.773A	13.2	0.699A	4.0	0.806A	13.2	0.732A
4.2	0.758A	13.3	0.690A	4.2	0.775A	13.3	0.707A	4.2	0.808A	13.3	0.740A
4.5	0.759A	13.5	0.698A	4.5	0.776A	13.5	0.715A	4.5	0.809A	13.5	0.748A
4.8	0.759A	13.8	0.700A	4.8	0.776A	13.8	0.717A	4.8	0.809A	13.8	0.750A
5.0	0.759A	14.0	0.701A	5.0	0.776A	14.0	0.718A	5.0	0.809A	14.0	0.751A
5.2	0.759A	14.2	0.701A	5.2	0.776A	14.2	0.718A	5.2	0.809A	14.2	0.751A
5.5	0.758A	14.5	0.700A	5.5	0.775A	14.5	0.717A	5.5	0.808A	14.5	0.750A
5.8	0.757A	14.8	0.699A	5.8	0.774A	14.8	0.716A	5.8	0.807A	14.8	0.749A
6.0	0.756A	15.0	0.698A	6.0	0.773A	15.0	0.715A	6.0	0.806A	15.0	0.748A
6.2	0.754A			6.2	0.771A			6.2	0.804A		
6.5	0.752A			6.5	0.769A			6.5	0.802A		
6.8	0.750A			6.8	0.767A			6.8	0.800A		
7.0	0.748A			7.0	0.765A			7.0	0.798A		
7.2	0.747A			7.2	0.764A			7.2	0.797A		
7.5	0.745A			7.5	0.762A			7.5	0.795A		
7.8	0.740A			7.8	0.757A			7.8	0.790A		
8.0	0.737A			8.0	0.754A			8.0	0.787A		
8.2	0.734A			8.2	0.751A			8.2	0.784A		
8.5	0.726A			8.5	0.743A			8.5	0.776A		
8.8	0.716A			8.8	0.733A			8.8	0.766A		
9.0	0.708A			9.0	0.725A			9.0	0.758A		
9.2	0.706A			9.2	0.723A			9.2	0.756A		
9.5	0.718A			9.5	0.735A			9.5	0.768A		
9.8	0.741A			9.8	0.758A			9.8	0.791A		
10.0	0.760A			10.0	0.777A			10.0	0.810A		
10.2	0.774A			10.2	0.791A			10.2	0.824A		
10.5	0.782A			10.5	0.799A			10.5	0.832A		

† VALUE FOLLOWED BY AN "A" IS PROVISIONAL.

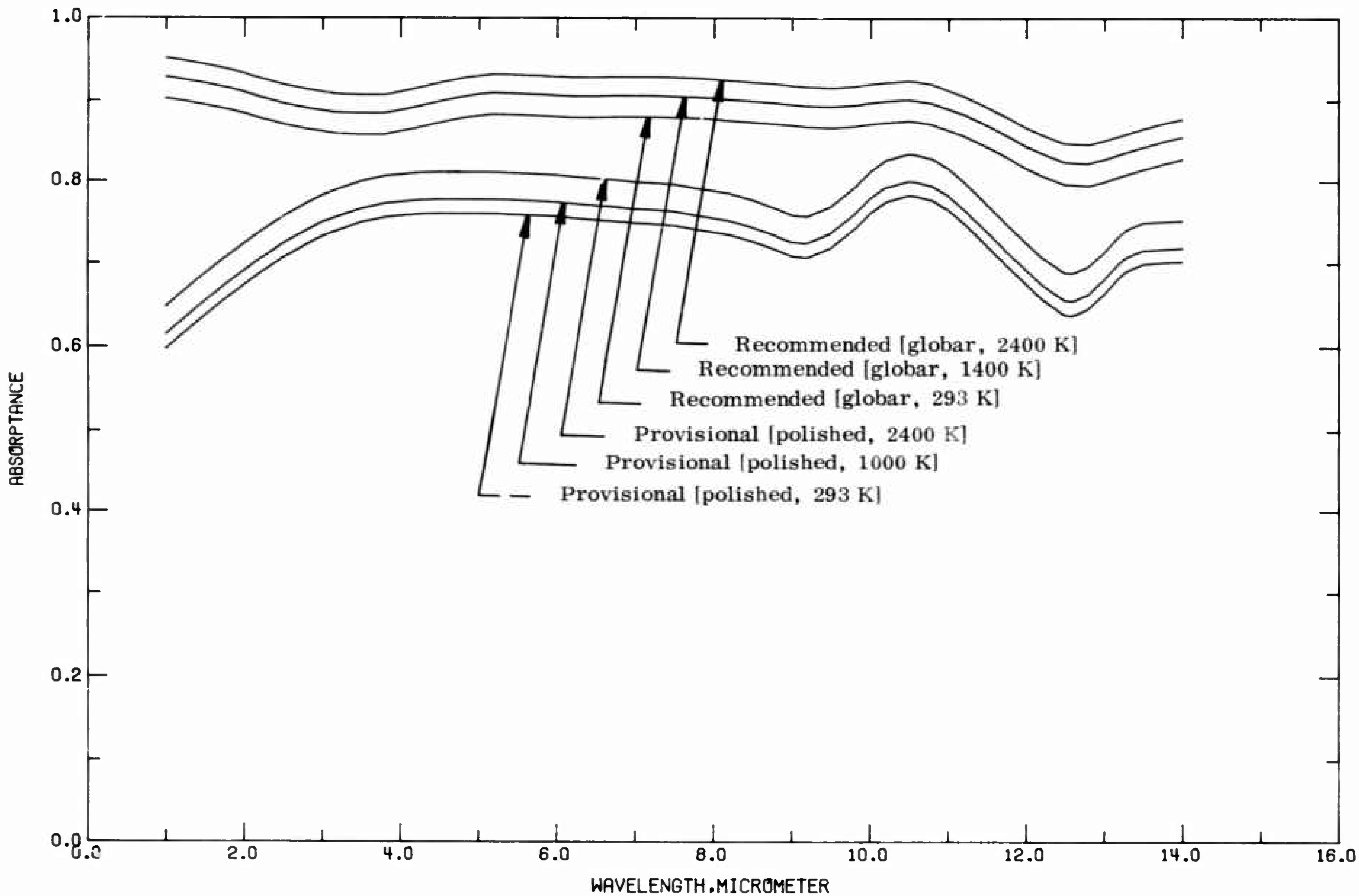


FIGURE 13-7. RECOMMENDED NORMAL SPECTRAL ABSORPTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE).

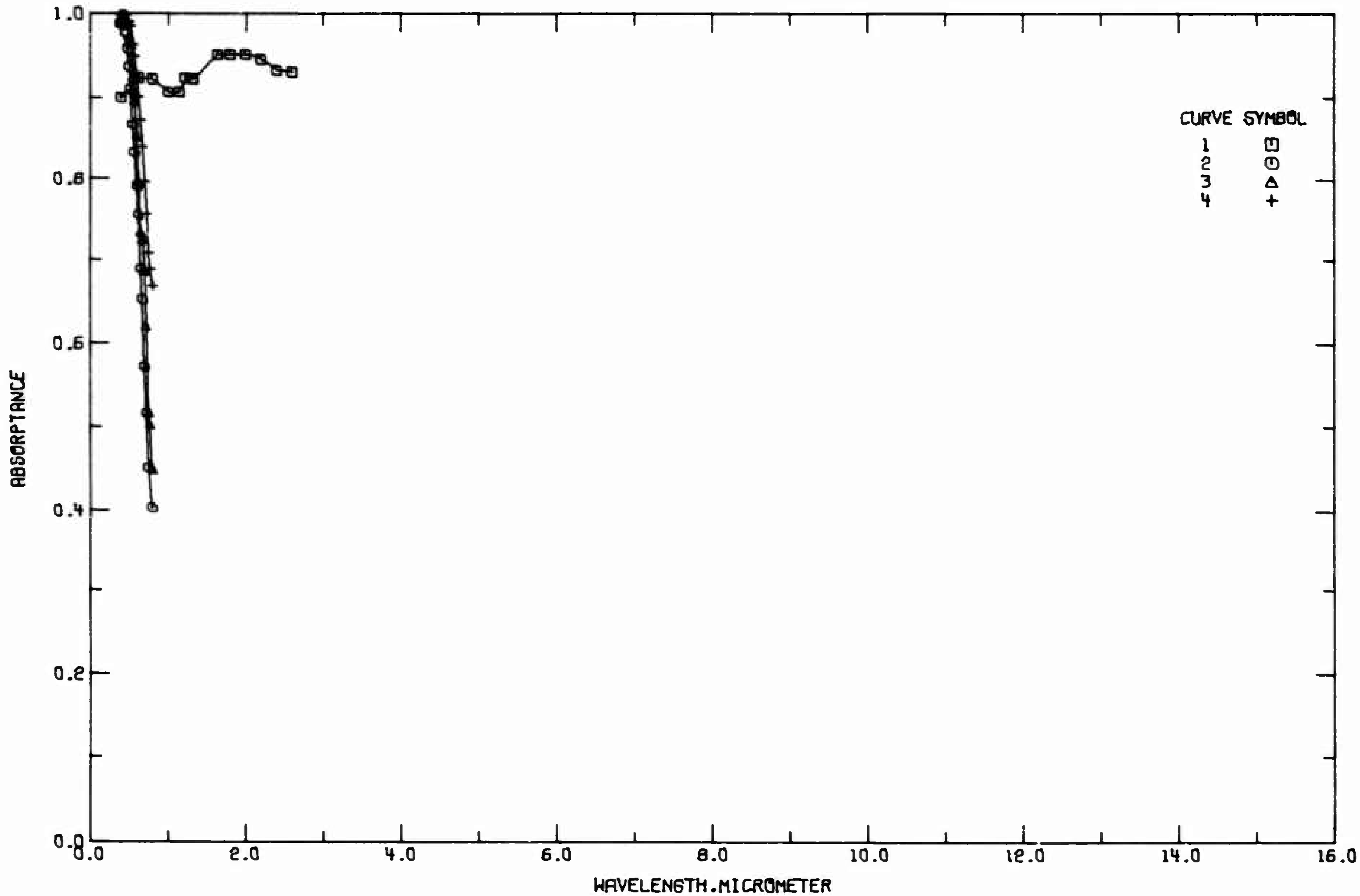


FIGURE 13-8. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE).

TABLE 13-11. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTION OF SILICON MONOCARBIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T32388	Byrne, R.F. and Mancinalli, L.N.	1954	0.40-2.60	≈298		Globar; data extracted from smooth curve; $\theta \approx 0°$.
2	T57246	Bunton, G.V.	1970	0.39-0.80	293	A	Film specimen 0.3 μm thick; deposited on glass at 300 K; electrical resistivity 446, 378, 357, 312, 292, 269, 237, 202, 179, and 163 Ω cm at 295, 303, 308, 315, 322, 328, 337, 346, and 353 K, respectively.
3	T57246	Bunton, G.V.	1970	0.39-0.80	293	B	Film specimen 0.3 μm thick; deposited on glass at 315 K; electrical resistivity 115, 100, 91.2, 83.9, 74.3, 66.7, 63.3, 55.3, 51.3, 42.9, 43.7, 40.5, 37.6, 34.4, 32.6, and 30.8 Ω cm at 294, 300, 303, 310, 314, 320, 323, 328, 333, 338, 342, 349, 354, 358, 362, and 367 K, respectively.
4	T57246	Bunton, G.V.	1970	0.39-0.80	293	C	Film specimen 0.5 μm thick; deposited on glass at 550 K; electrical resistivity 2800, 2180, 1880, 1730, 1570, 1380, 1250, 1150, 1040, 938, 857, 794, 736, 698, 638, and 601 Ω cm at 294, 308, 314, 319, 324, 328, 334, 338, 343, 349, 353, 359, 362, 365, 371, and 376 K, respectively.

TABLE 13-12. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α
CURVE 1	
T = 298.	
0.400	0.900
0.630	0.923
0.803	0.921
1.01	0.906
1.15	0.906
1.23	0.922
1.33	0.921
1.64	0.950
1.80	0.950
2.00	0.950
2.20	0.944
2.40	0.931
2.60	0.929
CURVE 2	
T = 293.	
0.386	0.987
0.404	0.987
0.422	0.987
0.452	0.976
0.481	0.957
0.504	0.935
0.524	0.909
0.550	0.867
0.571	0.833
0.604	0.790
0.622	0.754
0.651	0.688
0.671	0.652
0.701	0.572
0.724	0.515
0.752	0.451
0.798	0.403
CURVE 3	
T = 293.	
0.386	0.994
CURVE 3 (CONT.)	
0.404	0.994
0.422	0.994
0.452	0.993
0.471	0.988
0.502	0.973
0.523	0.963
0.554	0.924
0.572	0.896
0.603	0.853
0.624	0.796
0.651	0.733
0.674	0.724
0.702	0.686
0.721	0.620
0.755	0.518
0.772	0.503
0.804	0.450
CURVE 4	
T = 293.	
0.386	0.998
0.404	0.998
0.422	0.998
0.452	0.998
0.471	0.998
0.502	0.990
0.523	0.985
0.554	0.963
0.572	0.946
0.603	0.922
0.624	0.901
0.653	0.872
0.673	0.840
0.707	0.796
0.730	0.756
0.755	0.708
0.776	0.688
0.805	0.668

e. Normal Spectral Transmittance (Wavelength Dependence)

A total of 61 sets of data are available at room temperature. Thirty-one sets were measured below 1 μm and six sets above 15 μm.

Most of the data measured between 1 and 15 μm were for thin specimens with thickness ranging from several μm to over 300 μm and colored from colorless to dark green. A recommended curve applicable to colorless specimen with thickness ranging from 100 to 200 μm is generated following the data of Lipson [E17415] (Figure 13-10, curve 30). The values are typical above 5 μm where a series of peaks and valleys occur. Below 5 μm, the uncertainty is believed to be 10%.

Four sets of data were measured for thin films about 0.1 μm thick or thinner. One curve was generated following the data of Schatz, et al. [T22272] (Figure 13-10, curve 2) for a specimen 0.06 μm thick. The recommended values below 10 μm have an uncertainty of 5%. The values above 10 μm are typical.

The recommended and the typical curves are shown in Figure 13-9 and the experimental curves are shown in Figure 13-10. The recommended and the typical values, the experimental measurement information, and the experimental data are tabulated in Tables 13-13, 13-14, and 13-15, respectively.

TABLE 13-13. RECOMMENDED NORMAL SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
THIN, COLORLESS 100-200 μm THICK T = 293	
1.0	0.641
1.2	0.643
1.5	0.647
1.8	0.650
2.0	0.653
2.2	0.655
2.5	0.658
2.8	0.660
3.0	0.661
3.2	0.662
3.5	0.662
3.8	0.660
4.0	0.658
4.2	0.655A†
4.5	0.646A
4.8	0.631A
5.0	0.615B
5.2	0.592B
5.4	0.555B
5.5	0.528B
5.6	0.482B
5.65	0.438B
5.68	0.383B
5.7	0.342B
5.75	0.236B
5.8	0.130B
5.82	0.105B
5.86	0.070B
5.9	0.049B
6.0	0.014B
6.2	0.000A
6.26	0.070B
6.32	0.140B
6.39	0.000A
6.52	0.000A
6.6	0.175B
6.7	0.340B
6.75	0.411B
6.8	0.468B

λ	τ
THIN, COLORLESS 100-200 μm THICK T = 293 (CONT.)	
6.82	0.492B†
6.86	0.532B
6.95	0.400B
7.0	0.140B
7.04	0.101B
7.1	0.080B
7.2	0.059B
7.4	0.029B
7.5	0.017B
7.64	0.000A
7.76	0.000A
7.8	0.014B
7.9	0.067B
8.0	0.096B
8.05	0.103B
8.1	0.105B
8.2	0.103B
8.3	0.092B
8.5	0.080B
8.8	0.061B
8.9	0.058B
9.0	0.057B
9.1	0.056B
9.2	0.056B
9.3	0.057B
9.4	0.060B
9.5	0.065B
9.58	0.070B
9.62	0.071B
9.64	0.071B
9.68	0.069B
9.75	0.061B
9.8	0.051B
9.86	0.040B
9.9	0.032B
10.0	0.025B
10.1	0.011B
10.2	0.005B
10.6	0.002B

λ	τ
THIN, COLORLESS 100-200 μm THICK T = 293 (CONT.)	
10.8	0.000A†

λ	τ
THIN FILM THICKNESS 0.05 μm T = 293	
1.0	0.548
1.2	0.604
1.5	0.675
1.8	0.734
2.0	0.765
2.2	0.791
2.5	0.822
2.8	0.846
3.0	0.859
3.2	0.871
3.5	0.888
3.8	0.902
4.0	0.909
4.2	0.915
4.5	0.923
4.8	0.929
5.0	0.932
5.2	0.934
5.5	0.938
5.8	0.940
6.0	0.942
6.2	0.942
6.5	0.944
6.8	0.944
7.0	0.945
7.5	0.945
8.0	0.945
8.5	0.945
8.8	0.944
9.0	0.944
9.5	0.944
9.8	0.945
10.0	0.945
10.5	0.945A†
10.6	0.945A
10.8	0.944A
11.0	0.943A
11.2	0.938A
11.4	0.927B

λ	τ
THIN FILM THICKNESS 0.05 μm T = 293 (CONT.)	
11.5	0.914B†
11.6	0.893B
11.8	0.825B
11.9	0.762B
12.0	0.683B
12.1	0.572B
12.2	0.445B
12.3	0.272B
12.4	0.120B
12.45	0.065B
12.5	0.039B
12.55	0.026B
12.6	0.042B
12.65	0.088B
12.7	0.178B
12.75	0.298B
12.8	0.376B
12.9	0.490B
13.0	0.576B
13.1	0.635B
13.3	0.718B
13.5	0.774B
13.8	0.833B
14.0	0.862A
14.2	0.881A
14.4	0.893A
14.5	0.897A
14.6	0.899A
14.8	0.903A
15.0	0.902A

† VALUE FOLLOWED BY AN "A" IS PROVISIONAL AND BY A "B" IS TYPICAL.

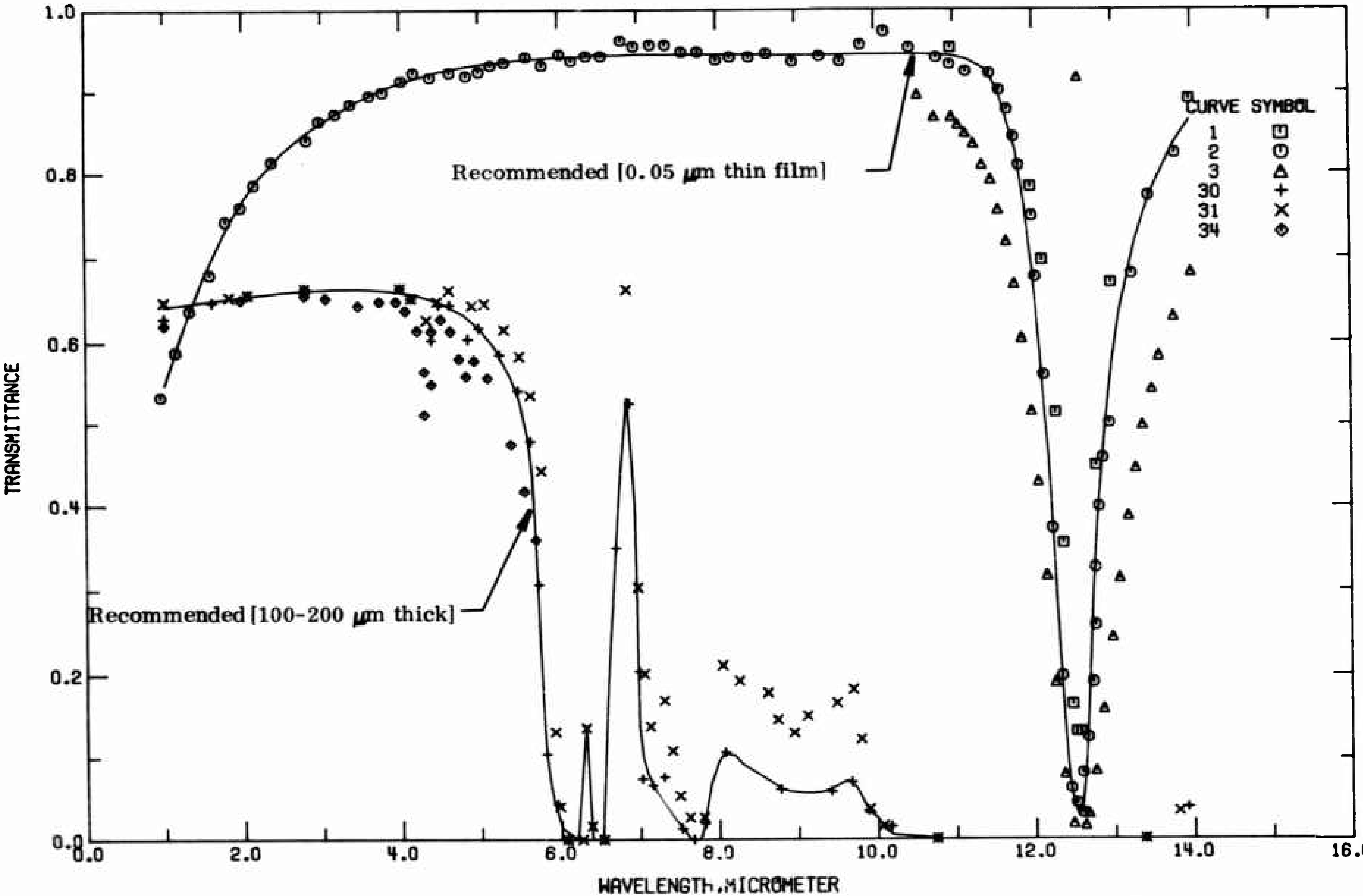


FIGURE 13-9. RECOMMENDED NORMAL SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE).

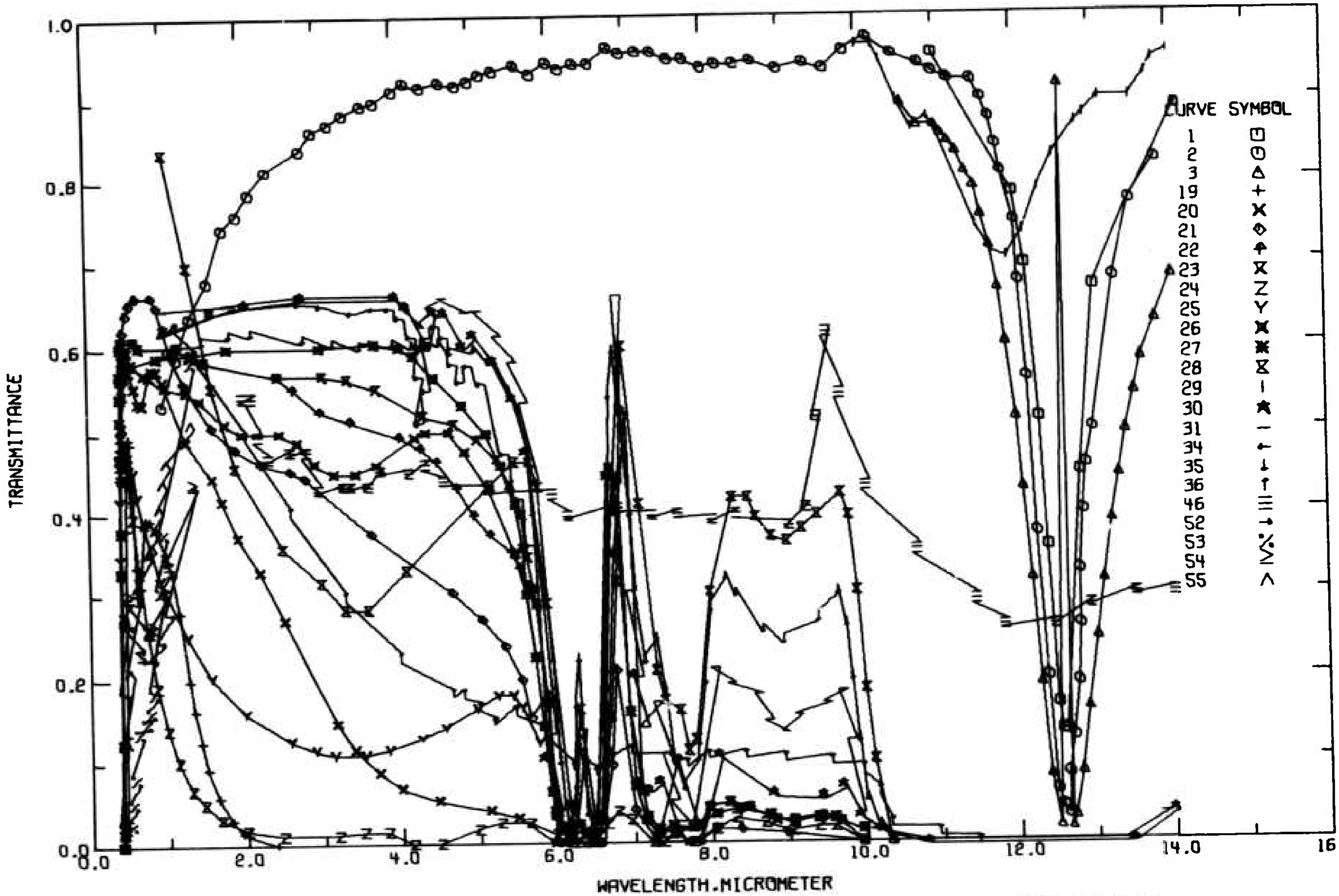


FIGURE 13-10. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE).

TABLE 13-14. MEASUREMENT INFORMATION ON THE SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T32822 E17420	Spitzer, W.G., Kleinman, D.A., and Frosch, C.J.	1959	11-14	293		β-phase polycrystalline cubic SiC film 0.04 μm thick; measured by a conventional sample in-sample out technique with a double-pass Perkin Elmer spectrometer; $\theta' = 0°$.
2	T32822 E17420	Spitzer, W.G., et al.	1959	0.95-15	293		Similar to the above except specimen thickness 0.06 μm.
3	T32822 E17420	Spitzer, W.G., et al.	1959	11-14	293		Similar to the above except specimen thickness 0.12 μm.
4	E02863	Namba, M.	1957	0.3-1.0	293		p-type colorless single crystal; electrical resistivity 10^4 Ω cm.
5	E02863	Namba, M.	1957	0.4-1.0	293		n-type green single crystal; electrical resistivity 10^2 Ω cm.
6	E02863	Namba, M.	1957	0.4-1.0	293		p-type black single crystal; electrical resistivity 0.1 Ω cm.
7	E03607	Lely, J.A. and Kröger, F.A.	1958	0.38-0.57	293	1.61	Hexagonal colorless crystal; 200 μm in thickness; prepared by sublimation at ~2773 K in a stream of pure argon; data taken from smooth curve.
8	E03607	Lely, J.A. and Kröger, F.A.	1958	0.42-0.62	293		From the same batch as the above specimen except surface covered by a thin layer of yellow cubic SiC.
9	E03607	Lely, J.A. and Kröger, F.A.	1958	0.39-0.43	77		Hexagonal; prepared by sublimation in argon; data taken from smooth curve.
10	E03607	Lely, J.A. and Kröger, F.A.	1958	0.40-0.45	292.5		The above specimen.
11	E03607	Lely, J.A. and Kröger, F.A.	1958	0.40-0.45	394		The above specimen.
12	E03607	Lely, J.A. and Kröger, F.A.	1958	0.41-0.46	461		The above specimen.
13	E03607	Lely, J.A. and Kröger, F.A.	1958	0.41-0.47	5.4		The above specimen.
14	E03607	Lely, J.A. and Kröger, F.A.	1958	0.42-0.47	585		The above specimen.
15	E03607	Lely, J.A. and Kröger, F.A.	1958	0.43-0.48	744		The above specimen.
16	E03607	Lely, J.A. and Kröger, F.A.	1958	0.44-0.49	800		The above specimen.
17	E03607	Lely, J.A. and Kröger, F.A.	1958	0.45-0.50	948		The above specimen.
18	E03607	Lely, J.A. and Kröger, F.A.	1958	0.46-0.51	1036		The above specimen.
19	E03607	Lely, J.A. and Kröger, F.A.	1958	0.40-2.4	293	101	1.5 x 10^{19} N; hexagonal; dark green; 135 μm in thickness; prepared by sublimation at ~2773 K in an Ar + 10% N_2 atm; data taken from smooth curve.
20	E03607	Lely, J.A. and Kröger, F.A.	1958	0.39-6.0	293	103	2.7 x 10^{16} N; hexagonal; green; 97 μm in thickness; prepared by sublimation at ~2773 K in an Ar + 0.1% N_2 atm; data taken from smooth curve.
21	E03607	Lely, J.A. and Kröger, F.A.	1958	0.39-9.9	293	131	Hexagonal; colorless; ~270 μm in thickness; prepared by sublimation at ~2773 K in an Ar + 0.01% N_2 atm; data taken from smooth curve.

TABLE 13-14. MEASUREMENT INFORMATION ON THE SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
22	E03607	Lely, J.A. and Kröger, F.A.	1958	0.39-9.9	293	130	Hexagonal; colorless; 230 μm in thickness; prepared by sublimation at ~2773 K in an Ar + 0.001% N_2 atm; data taken from smooth curve.
23	E03607	Lely, J.A. and Kröger, F.A.	1958	0.39-9.9	293	132	Hexagonal; colorless; 215 μm in thickness; prepared by sublimation at ~2773 K in pure argon; data taken from smooth curve.
24	E03607	Lely, J.A. and Kröger, F.A.	1958	0.38-9.9	293	96	10^{19} Al; hexagonal; blue; 107 μm in thickness; prepared by sublimation at ~2773 K in an Ar + 0.51% $AlCl_3$ atm; data taken from smooth curve.
25	E03607	Lely, J.A. and Kröger, F.A.	1958	0.37-5.8	293	201	5.7 x 10^{18} Al; hexagonal; blue; 66 μm in thickness; prepared by sublimation at ~2773 K in an Ar + 0.51% $AlCl_3$ atm; data taken from smooth curve.
26	E03607	Lely, J.A. and Kröger, F.A.	1958	0.38-9.9	293	98	~10^{18} Al; hexagonal; light blue; 200 μm in thickness; prepared by sublimation at ~2773 K in an Ar + 0.0085% $AlCl_3$ atm; data taken from smooth curve.
27	E03607	Lely, J.A. and Kröger, F.A.	1958	0.38-9.9	293	115	Hexagonal; colorless; prepared by sublimation at ~2773 K in pure argon; data taken from smooth curve.
28	E03607	Lely, J.A. and Kröger, F.A.	1958	1.0-10	293	188	~2 x 10^{18} Al; hexagonal; light blue; 155 μm in thickness; prepared by sublimation at ~2773 K in an Ar + 0.076% $AlCl_3$ atm; data taken from smooth curve.
29	E03607	Lely, J.A. and Kröger, F.A.	1958	10-14	293		Cubic; yellow; data taken from smooth curve.
30	E17415	Lipson, H.G.	1960	1.0-25	293	S-25	α-II hexagonal crystal 0.155 mm thick; obtained from General Electric Co.; as grown; measured by the conventional in-out technique; data taken from smooth curve.
31	E17415	Lipson, H.G.	1960	1.0-24	293	S-25	Similar to the above except specimen 0.11 mm thick.
32	E17415	Lipson, H.G.	1960	14-24	293	S-25	Similar to the above except specimen 0.105 mm thick and surface polished.
33	E17415	Lipson, H.G.	1960	14-24	293	S-25	Similar to the above except specimen 0.145 mm thick.
34	E17415	Lipson, H.G.	1960	1.0-5.7	293	R-256	α-II hexagonal crystal 0.27 mm thick; obtained from Westinghouse Research Lab.; measured by the conventional in-out technique; data taken from smooth curve.
35	E17415	Lipson, H.G.	1960	1.0-10	293	R-278	Similar to the above except specimen 0.07 mm thick.
36	E17415	Lipson, H.G.	1960	1.0-11	293		α-II hexagonal; light green crystal 0.007 mm thick; obtained from Norton Co.; measured by the conventional in-out technique; data taken from smooth curve.
37	T35131	Dalven, R.	1965	0.44-0.76	295		β-phase n-type cubic single crystal; < 10^{17} cm^{-3} each of Al, B, Ca, Fe, and Mg; about 2 mm in diameter and 0.114 mm thick; grown an extension of Kendall's method; polished; measured by the conventional in-out technique with unpolarized light normal to the polished surface 17° to a < 111 > direction.
38	T35131	Dalven, R.	1965	0.44-0.76	351		The above specimen.
39	T35131	Dalven, R.	1965	0.45-0.76	400		The above specimen.
40	T35131	Dalven, R.	1965	0.46-0.76	450		The above specimen.
41	T35131	Dalven, R.	1965	0.46-0.76	499		The above specimen.
42	T35131	Dalven, R.	1965	0.47-0.76	550		The above specimen.
43	T35131	Dalven, R.	1965	0.47-0.76	601		The above specimen.
44	T35131	Dalven, R.	1965	0.48-0.76	652		The above specimen.
45	T35131	Dalven, R.	1965	0.48-0.76	700		The above specimen.

TABLE 13-14. MEASUREMENT INFORMATION ON THE SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
46	T60470	Brame, E.G., Jr., Margrave, J.L., and Meloche, V.W.	1957	2.0-16	293		High-purity; 12 mm diameter x 1 mm thick; measured by KBr disk method; data taken from smooth curve.
47	T32121	Pichugin, I.G. and Pikhtin, A.N.	1966	0.14-0.19	293		6H single crystal; pure; grown at 2723 K; data taken from smooth curve.
48	T32121	Pichugin, I.G. and Pikhtin, A.N.	1966	0.14-0.19	293	171	Similar to the above specimen except 0.0025 B-doped; acceptor concentration N_A = 2.70 x 10^{18} cm^{-3}; donor concentration N_D = 8.1 x 10^{17} cm^{-3}.
49	T32121	Pichugin, I.G. and Pikhtin, A.N.	1966	0.14-0.19	293	172	Similar to the above specimen except 0.0033 B-doped; N_A and N_D not given.
50	T32121	Pichugin, I.G. and Pikhtin, A.N.	1966	0.14-0.19	293	173	Similar to the above specimen except 0.0037 B-doped; N_A = 4.40 x 10^{18} cm^{-3}; N_D = 4.4 x 10^{17} cm^{-3}.
51	T32121	Pichugin, I.G. and Pikhtin, A.N.	1966	0.14-0.18	293	175	Similar to the above specimen except 0.091 B-doped; N_A and N_D not given.
52	T65652	Il'in, M.A., Kosaganova, M.G., Solomatin, V.N., Barinov, Yu.V., and Bulgakov, Yu.V.	1971	0.40-1.4	293	D-2-353 P1	6H α-phase p-type single crystal; B-doped; 480 μm thick; obtained by evaporating β-SiC; electrical resistivity 625 Ω cm; carrier concentration 2.1 x 10^{14} cm^{-3}.
53	T65652	Il'in, M.A., et al.	1971	0.46-1.3	293		The above specimen neutron-irradiated by a dose of 3.9 x 10^{15} cm^{-2}; electrical resistivity 10^7 Ω cm.
54	T65652	Il'in, M.A., et al.	1971	0.43-1.4	293	D-2-336 P2	6H α-phase p-type single crystal; B-doped; 310 μm thick; obtained by evaporating β-SiC; electrical resistivity 302 Ω cm; carrier concentration 5.2 x 10^{14} cm^{-3}.
55	T65652	Il'in, M.A., et al.	1971	0.45-1.3	293		The above specimen neutron-irradiated by a dose of 2.3 x 10^{15} cm^{-2}; electrical resistivity 1.2 x 10^4 Ω cm; carrier concentration 0.7 x 10^{14} cm^{-3}.
56	T65652	Il'in, M.A., et al.	1971	0.40-1.0	293	S-3-273 PA4	6H α-phase p-type single crystal; B-doped; 400 μm thick; obtained by evaporating pure silicon and graphite; electrical resistivity 200 Ω cm; carrier concentration 4 x 10^{14} cm^{-3}; data taken from smooth curve.
57	T65652	Il'in, M.A., et al.	1971	0.40-1.0	293		The above specimen α-irradiated by a dose of 3.6 x 10^{13} cm^{-2}; electrical resistivity 642 Ω cm; carrier concentration 2.36 x 10^{14} cm^{-3}.
58	T63770	Il'in, M.A., Rashevskaya, E.P., and Buras, E.M.	1971	15-21	293		6H α-phase n-type single crystal; light polarized parallel to c-axis; data taken from smooth curve.
59	T63770	Il'in, M.A., et al.	1971	15-21	293		Similar to the above specimen except light polarized perpendicular to c-axis.
60	T63770	Il'in, M.A., et al.	1971	15-21	293		6H α-phase p-type single crystal; light polarized parallel to c-axis.
61	T63770	Il'in, M.A., et al.	1971	15-21	293		Similar to the above specimen except light polarized perpendicular to c-axis.

TABLE 13-15. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 1	
T = 293.	
10.98	0.953
11.98	0.782
12.12	0.695
12.28	0.513
12.37	0.354
12.48	0.165
12.53	0.132
12.58	0.132
12.79	0.447
12.99	0.668
14.00	0.889
CURVE 2	
T = 293.	
0.95	0.533
1.14	0.588
1.32	0.636
1.58	0.679
1.79	0.742
1.98	0.759
2.15	0.785
2.38	0.813
2.82	0.839
2.98	0.862
3.19	0.871
3.38	0.883
3.62	0.894
3.79	0.898
4.03	0.912
4.18	0.922
4.39	0.916
4.64	0.922
4.85	0.918
5.01	0.923
5.16	0.931
5.33	0.935
5.61	0.942
5.81	0.931

λ	τ
CURVE	2(CONT.)
6.03	0.945
6.18	0.937
6.37	0.943
6.56	0.943
6.81	0.962
6.97	0.955
7.18	0.957
7.37	0.957
7.58	0.948
7.78	0.948
8.01	0.938
8.19	0.942
8.43	0.942
8.65	0.946
8.98	0.936
9.32	0.943
9.58	0.936
9.84	0.957
10.14	0.973
10.46	0.953
10.80	0.941
10.97	0.932
11.17	0.923
11.47	0.921
11.59	0.900
11.69	0.876
11.77	0.842
11.83	0.808
11.99	0.747
12.03	0.675
12.13	0.560
12.23	0.372
12.35	0.198
12.45	0.062
12.52	0.043
12.60	0.031
12.60	0.081
12.67	0.125
12.74	0.191
12.77	0.258

λ	τ
CURVE	2(CONT.)
12.77	0.325
12.82	0.398
12.87	0.456
12.96	0.500
13.25	0.679
13.47	0.771
13.81	0.822
14.13	0.890
14.33	0.878
14.53	0.898
14.97	0.897
CURVE 3	
T = 293.	
10.56	0.895
10.77	0.867
10.99	0.867
11.07	0.857
11.16	0.847
11.26	0.834
11.37	0.809
11.48	0.791
11.57	0.755
11.67	0.718
11.77	0.667
11.86	0.603
11.98	0.515
12.06	0.428
12.16	0.316
12.26	0.191
12.37	0.080
12.48	0.019
12.58	0.009
12.63	0.016
12.67	0.031
12.77	0.084
12.87	0.160
12.99	0.244
13.08	0.313

λ	τ
CURVE	3(CONT.)
13.19	0.387
13.29	0.444
13.38	0.498
13.50	0.543
13.59	0.583
13.78	0.628
14.00	0.681
CURVE 4*	
T = 293.	
0.334	0.0
0.367	0.0
0.391	0.012
0.398	0.094
0.406	0.200
0.417	0.308
0.452	0.372
0.500	0.408
0.600	0.453
0.700	0.476
0.800	0.508
0.900	0.518
1.000	0.527
CURVE 5*	
T = 293.	
0.398	0.118
0.406	0.212
0.417	0.293
0.452	0.363
0.501	0.399
0.602	0.432
0.700	0.434
0.800	0.434
0.900	0.442
1.000	0.434

λ	τ
CURVE 6*	
T = 293.	
0.400	0.0
0.500	0.0
0.600	0.0
0.700	0.0
0.750	0.014
0.777	0.057
0.800	0.107
0.820	0.156
0.843	0.197
0.900	0.199
0.950	0.203
1.000	0.203
CURVE 7*	
T = 293.	
0.381	0.0
0.389	0.012
0.394	0.030
0.396	0.052
0.400	0.181
0.406	0.366
0.412	0.509
0.414	0.539
0.418	0.565
0.422	0.581
0.430	0.593
0.438	0.602
0.511	0.605
0.569	0.604
CURVE 8*	
T = 293.	
0.417	0.0
0.428	0.009
0.438	0.028
0.446	0.050
0.454	0.086

λ	τ
CURVE	8(CONT.)*
0.467	0.176
0.499	0.478
0.508	0.534
0.512	0.555
0.518	0.567
0.526	0.572
0.537	0.571
0.548	0.569
0.568	0.557
0.515	0.521
CURVE 9*	
T = 77.	
0.391	0.0
0.393	0.055
0.395	0.118
0.398	0.310
0.402	0.554
0.403	0.627
0.406	0.704
0.409	0.752
0.415	0.814
0.432	0.912
CURVE 10*	
T = 292.5	
0.397	0.0
0.400	0.055
0.402	0.101
0.407	0.299
0.412	0.484
0.415	0.560
0.420	0.650
0.426	0.735
0.436	0.827
0.450	0.878

*NOT SHOWN IN FIGURE.

TABLE 13-15. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

CURVE 11*
T = 394.

λ	τ
0.402	0.0
0.406	0.062
0.410	0.149
0.417	0.374
0.425	0.625
0.429	0.721
0.432	0.762
0.437	0.809
0.442	0.843
0.450	0.878

CURVE 12*
T = 461.

λ	τ
0.406	0.0
0.409	0.045
0.414	0.099
0.417	0.181
0.426	0.469
0.433	0.667
0.437	0.747
0.441	0.791
0.451	0.861
0.460	0.892

CURVE 13*
T = 514.

λ	τ
0.410	0.0
0.414	0.042
0.418	0.104
0.423	0.204
0.431	0.496
0.437	0.651
0.441	0.739
0.449	0.806
0.457	0.854
0.467	0.896

CURVE 14*
T = 585.

λ	τ
0.417	0.0
0.422	0.046
0.427	0.130
0.430	0.226
0.438	0.560
0.442	0.677
0.447	0.742
0.452	0.794
0.460	0.843
0.471	0.891

CURVE 15*
T = 744.

λ	τ
0.429	0.0
0.433	0.036
0.438	0.096
0.443	0.240
0.454	0.607
0.460	0.737
0.465	0.807
0.470	0.857
0.475	0.884
0.481	0.911

CURVE 16*
T = 800.

λ	τ
0.435	0.0
0.440	0.032
0.444	0.085
0.449	0.191
0.464	0.659
0.469	0.777
0.473	0.822
0.477	0.856
0.481	0.879
0.486	0.903

CURVE 17*
T = 948.

λ	τ
0.447	0.0
0.451	0.030
0.456	0.072
0.461	0.163
0.477	0.628
0.483	0.754
0.487	0.816
0.491	0.862
0.494	0.890
0.498	0.914

CURVE 18*
T = 1036.

λ	τ
0.457	0.0
0.463	0.038
0.466	0.085
0.471	0.157
0.489	0.644
0.492	0.717
0.496	0.789
0.500	0.844
0.512	0.921

CURVE 19
T = 293.

λ	τ
0.397	0.0
0.420	0.017
0.437	0.033
0.450	0.134
0.461	0.297
0.472	0.382
0.484	0.440
0.500	0.478
0.518	0.495
0.529	0.489
0.551	0.435
0.566	0.419

CURVE 19(CONT.)

λ	τ
0.593	0.336
0.603	0.302
0.624	0.291
0.641	0.310
0.705	0.384
0.726	0.393
0.771	0.393
0.865	0.379
0.973	0.353
1.05	0.326
1.14	0.279
1.26	0.198
1.32	0.162
1.41	0.124
1.50	0.093
1.64	0.059
1.81	0.031
1.95	0.015
2.40	0.0

CURVE 20
T = 293.

λ	τ
0.389	0.0
0.396	0.123
0.407	0.378
0.413	0.461
0.422	0.498
0.438	0.510
0.450	0.547
0.470	0.568
0.489	0.574
0.536	0.574
0.599	0.555
0.646	0.537
0.702	0.535
0.795	0.568
0.836	0.575
0.887	0.575
0.973	0.562

CURVE 20(CONT.)

λ	τ
1.26	0.491
1.59	0.445
1.71	0.416
1.91	0.371
2.20	0.328
2.51	0.269
3.17	0.146
3.40	0.115
3.71	0.088
4.00	0.069
4.48	0.054
5.14	0.042
5.50	0.033
5.97	0.0

CURVE 21
T = 293.

λ	τ
0.389	0.0
0.396	0.123
0.407	0.378
0.418	0.568
0.428	0.603
0.465	0.622
0.510	0.642
0.554	0.654
0.633	0.663
0.836	0.663
0.904	0.651
1.08	0.594
1.24	0.560
1.60	0.508
1.91	0.481
2.24	0.463
2.62	0.453
2.81	0.444
3.66	0.374
4.69	0.302
5.07	0.269
5.36	0.237

CURVE 21(CONT.)

λ	τ
5.57	0.198
5.68	0.152
5.90	0.180
5.99	0.0
6.59	0.028
6.71	0.095
6.79	0.209
7.00	0.041
7.28	0.0
7.82	0.0
8.04	0.017
8.36	0.016
8.94	0.011
9.94	0.0

CURVE 22
T = 293.

λ	τ
0.389	0.0
0.396	0.123
0.407	0.378
0.421	0.569
0.429	0.601
0.448	0.610
0.597	0.610
0.668	0.603
1.16	0.603
1.36	0.592
1.52	0.585
2.47	0.567
2.66	0.552
3.01	0.526
3.40	0.514
4.03	0.495
4.30	0.481
4.51	0.464
4.77	0.431
4.98	0.397
5.19	0.373
5.46	0.352

*NOT SHOWN IN FIGURE.

TABLE 13-15. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 22 (CONT.)	
5.56	0.332
5.66	0.310
5.76	0.286
5.89	0.171
5.95	0.034
6.08	0.020
6.27	0.023
6.43	0.0
6.58	0.027
6.73	0.402
6.83	0.440
6.95	0.158
7.10	0.064
7.15	0.033
7.31	0.016
7.55	0.001
7.81	0.019
7.95	0.044
8.21	0.049
8.47	0.043
8.81	0.027
9.03	0.027
9.40	0.032
9.64	0.025
9.93	0.015
CURVE 23	
T = 293.	
0.389	0.0
0.396	0.123
0.407	0.378
0.420	0.569
0.429	0.601
0.447	0.610
0.597	0.610
0.668	0.603
1.16	0.603
1.35	0.592
1.52	0.585

λ	τ
CURVE 23 (CONT.)	
2.47	0.567
3.05	0.567
3.37	0.563
3.74	0.551
4.34	0.520
4.74	0.510
5.04	0.491
5.29	0.466
5.45	0.434
5.59	0.397
5.66	0.345
5.76	0.286
5.89	0.171
5.96	0.034
6.08	0.020
6.27	0.023
6.43	0.0
6.57	0.027
6.73	0.402
6.83	0.441
6.95	0.158
7.10	0.064
7.15	0.033
7.31	0.016
7.55	0.011
7.81	0.019
7.95	0.044
8.21	0.049
8.47	0.043
8.81	0.027
9.04	0.027
9.40	0.032
9.64	0.025
9.93	0.015
CURVE 24	
T = 293.	
0.381	0.0
0.391	0.016

λ	τ
CURVE 24 (CONT.)	
0.400	0.328
0.409	0.471
0.419	0.488
0.431	0.500
0.447	0.488
0.469	0.474
0.501	0.466
0.556	0.396
0.628	0.329
0.725	0.259
0.846	0.192
0.978	0.140
1.11	0.102
1.28	0.069
1.44	0.052
1.65	0.033
1.99	0.019
2.46	0.011
3.17	0.011
3.50	0.015
3.81	0.015
4.14	0.0
4.49	0.0
4.98	0.018
5.27	0.026
5.64	0.026
5.98	0.011
6.13	0.011
6.34	0.0
6.53	0.011
6.64	0.024
6.78	0.040
6.95	0.029
7.22	0.0
7.36	0.0
7.47	0.011
7.73	0.0
8.04	0.016
8.30	0.030
8.67	0.024

λ	τ
CURVE 24 (CONT.)	
9.02	0.013
9.36	0.019
9.57	0.019
9.93	0.0
CURVE 25	
T = 293.	
0.374	0.0
0.379	0.024
0.392	0.345
0.402	0.416
0.408	0.440
0.421	0.446
0.430	0.480
0.442	0.460
0.469	0.470
0.515	0.457
0.574	0.453
0.622	0.421
0.702	0.385
0.900	0.319
1.24	0.250
1.55	0.203
1.99	0.159
2.57	0.125
2.89	0.114
3.13	0.108
3.53	0.108
3.84	0.114
4.26	0.127
4.57	0.140
4.98	0.163
5.26	0.179
5.45	0.179
5.56	0.165
5.78	0.122

λ	τ
CURVE 26	
T = 293.	
0.381	0.0
0.391	0.016
0.400	0.328
0.409	0.471
0.414	0.516
0.419	0.543
0.430	0.565
0.452	0.589
0.480	0.597
0.512	0.598
0.570	0.584
0.733	0.571
1.00	0.556
1.27	0.550
1.45	0.540
1.77	0.512
1.99	0.500
2.48	0.500
2.71	0.489
2.93	0.462
3.18	0.449
3.46	0.449
3.73	0.460
4.23	0.494
4.37	0.500
4.67	0.500
4.87	0.476
5.18	0.429
5.50	0.349
5.64	0.299
5.74	0.224
5.84	0.141
5.99	0.039
6.15	0.048
6.34	0.011
6.44	0.011
6.50	0.034
6.69	0.445
6.73	0.455

λ	τ
CURVE 26 (CONT.)	
6.78	0.444
7.00	0.070
7.13	0.028
7.28	0.012
7.48	0.021
7.73	0.018
8.04	0.035
8.34	0.042
8.73	0.034
9.04	0.023
9.36	0.031
9.57	0.031
9.93	0.0
CURVE 27	
T = 293.	
0.381	0.0
0.391	0.016
0.400	0.328
0.409	0.471
0.414	0.516
0.419	0.543
0.430	0.565
0.458	0.579
0.561	0.582
0.900	0.590
1.37	0.594
1.82	0.600
3.02	0.600
3.72	0.604
4.04	0.600
4.22	0.590
4.49	0.564
4.84	0.532
5.15	0.498
5.33	0.459
5.51	0.409
5.60	0.356
5.63	0.299

TABLE 13-15. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 27 (CONT.)	
5.74	0.224
5.84	0.141
5.92	0.064
5.99	0.039
6.15	0.348
6.34	0.011
6.44	0.011
6.50	0.034
6.69	0.445
6.73	0.455
6.78	0.444
7.00	0.070
7.13	0.028
7.28	0.012
7.48	0.021
7.73	0.018
8.04	0.035
8.34	0.042
8.73	0.034
9.04	0.023
9.36	0.031
9.57	0.031
9.93	0.0
CURVE 28	
T = 293.	
1.0	0.837
1.3	0.699
1.6	0.554
1.9	0.458
2.5	0.357
3.0	0.314
3.3	0.281
3.6	0.281
4.1	0.329
5.2	0.434
5.5	0.463
5.7	0.463
5.8	0.432

λ	τ
CURVE 28 (CONT.)	
5.9	0.288
6.2	0.000
6.3	0.162
6.5	0.000
6.7	0.153
6.8	0.314
6.9	0.600
7.1	0.410
7.3	0.208
7.4	0.172
7.6	0.160
7.7	0.111
7.8	0.124
8.0	0.300
8.3	0.417
8.5	0.417
8.6	0.393
8.8	0.368
9.0	0.362
9.2	0.378
9.4	0.395
9.7	0.422
9.8	0.394
9.9	0.301
10.0	0.185
10.1	0.100
10.3	0.000
CURVE 29	
T = 293.	
10.0	0.964
10.2	0.964
10.3	0.946
10.5	0.899
10.7	0.863
10.9	0.877
11.0	0.861
11.5	0.742
11.7	0.710

λ	τ
CURVE 29 (CONT.)	
11.9	0.703
12.1	0.734
12.3	0.786
12.5	0.828
12.8	0.869
12.9	0.878
13.1	0.899
13.5	0.899
13.7	0.927
13.8	0.944
14.0	0.953
CURVE 30	
T = 293.	
1.00	0.627
1.61	0.646
2.06	0.655
2.78	0.663
3.99	0.663
4.13	0.651
4.39	0.602
4.48	0.643
4.62	0.643
4.85	0.603
4.99	0.616
5.25	0.585
5.48	0.541
5.64	0.477
5.73	0.306
5.82	0.105
5.95	0.043
6.07	0.0
6.53	0.0
6.71	0.349
6.89	0.525
6.99	0.204
7.02	0.074
7.15	0.066
7.30	0.076

λ	τ
CURVE 30 (CONT.)	
7.52	0.013
7.67	0.0
7.81	0.019
8.07	0.107
8.77	0.061
9.41	0.058
9.67	0.070
9.88	0.034
10.17	0.015
10.75	0.0
13.39	0.0
13.93	0.038
14.38	0.078
14.84	0.139
15.23	0.186
15.60	0.223
16.00	0.255
16.62	0.294
17.25	0.323
17.83	0.344
18.22	0.358
19.02	0.368
20.18	0.374
22.09	0.384
24.62	0.397
CURVE 31	
T = 293.	
1.00	0.646
1.83	0.652
2.06	0.655
2.78	0.663
3.99	0.663
4.13	0.651
4.33	0.625
4.46	0.647
4.61	0.660
4.90	0.642
5.06	0.644

λ	τ
CURVE 31 (CONT.)	
5.31	0.614
5.50	0.583
5.64	0.535
5.77	0.441
5.93	0.132
5.98	0.039
6.07	00.0
6.26	00.0
6.32	0.137
6.38	0.016
6.53	0.0
6.86	0.661
6.98	0.303
7.06	0.201
7.13	0.139
7.31	0.170
7.41	0.109
7.50	0.053
7.62	0.026
7.80	0.026
8.05	0.211
8.26	0.193
8.62	0.179
8.74	0.147
8.95	0.131
9.12	0.152
9.49	0.167
9.70	0.183
9.80	0.123
9.90	0.036
10.07	0.016
10.75	0.0
13.39	0.0
13.82	0.033
14.29	0.122
14.73	0.191
15.19	0.258
15.57	0.291
16.22	0.333
16.73	0.360

λ	τ
CURVE 31 (CONT.)	
17.55	0.395
18.18	0.421
18.91	0.435
19.78	0.450
21.04	0.462
22.58	0.474
24.33	0.480
CURVE 32*	
T = 293.	
14.00	0.074
14.95	0.222
15.31	0.272
15.59	0.307
16.05	0.342
16.28	0.359
16.82	0.380
17.59	0.411
18.18	0.426
18.96	0.439
20.15	0.451
21.75	0.461
22.34	0.462
23.28	0.466
24.12	0.467
CURVE 33*	
T = 293.	
14.05	0.057
14.79	0.159
15.34	0.221
15.87	0.279
16.10	0.294
16.51	0.319
16.95	0.342
17.63	0.369
18.34	0.390
18.95	0.405

*NOT SHOWN IN FIGURE.

TABLE 13-15. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 33(CONT.)*	
19.39	0.414
19.98	0.420
20.52	0.429
21.97	0.439
22.97	0.446
24.05	0.453
CURVE 34	
T = 293.	
1.00	0.619
1.97	0.649
2.78	0.654
3.05	0.651
3.46	0.642
3.73	0.647
3.94	0.647
4.06	0.636
4.21	0.613
4.30	0.565
4.30	0.511
4.39	0.549
4.39	0.612
4.51	0.626
4.63	0.612
4.74	0.580
4.83	0.559
4.93	0.578
5.10	0.557
5.39	0.473
5.56	0.417
5.70	0.359
CURVE 35	
T = 293.	
1.00	0.597
1.50	0.611
1.85	0.618
2.14	0.620
CURVE 35(CONT.)	
2.81	0.612
3.19	0.607
3.54	0.603
3.96	0.607
4.21	0.604
4.29	0.599
4.43	0.603
4.56	0.607
4.70	0.596
5.01	0.599
5.21	0.584
5.45	0.550
5.65	0.499
5.73	0.401
5.88	0.302
5.96	0.224
6.03	0.101
6.09	0.046
6.15	0.017
6.23	0.072
6.24	0.168
6.29	0.223
6.33	0.132
6.37	0.039
6.45	0.019
6.56	0.037
6.62	0.192
6.70	0.394
6.73	0.543
6.79	0.596
6.88	0.510
6.98	0.399
7.03	0.291
7.15	0.220
7.29	0.247
7.40	0.188
7.51	0.099
7.63	0.069
7.81	0.103
7.92	0.196
CURVE 35(CONT.)	
8.00	0.281
8.20	0.320
8.33	0.299
8.68	0.255
8.94	0.241
9.39	0.268
9.65	0.301
9.75	0.262
9.82	0.199
9.90	0.124
9.99	0.055
10.15	0.022
10.34	0.0
CURVE 36	
T = 293.	
1.00	0.621
1.16	0.628
1.39	0.596
2.04	0.499
2.61	0.404
3.30	0.299
4.00	0.226
4.67	0.182
4.81	0.182
5.01	0.167
5.20	0.148
5.48	0.161
5.84	0.137
6.20	0.094
6.24	0.109
6.34	0.109
6.49	0.088
6.68	0.109
6.96	0.113
7.47	0.102
7.67	0.096
7.95	0.106
8.43	0.106
CURVE 36(CONT.)	
8.94	0.102
9.54	0.099
9.95	0.089
10.15	0.063
10.30	0.024
10.92	0.012
11.43	0.0
CURVE 37*	
T = 295.	
0.438	0.006
0.444	0.015
0.450	0.031
0.456	0.052
0.463	0.086
0.470	0.131
0.478	0.191
0.486	0.274
0.496	0.371
0.505	0.469
0.515	0.517
0.527	0.540
0.544	0.551
0.556	0.556
0.570	0.567
0.585	0.573
0.602	0.589
0.621	0.592
0.642	0.597
0.664	0.607
0.691	0.610
0.721	0.618
0.757	0.627
CURVE 38*	
T = 351.	
0.444	0.007
0.450	0.018
CURVE 38(CONT.)*	
0.456	0.037
0.463	0.058
0.476	0.096
0.478	0.148
0.486	0.217
0.495	0.311
0.505	0.420
0.515	0.497
0.528	0.533
0.543	0.558
0.555	0.563
0.570	0.570
0.585	0.572
0.602	0.581
0.620	0.588
0.642	0.595
0.664	0.608
0.631	0.618
0.722	0.630
0.757	0.666
CURVE 39*	
T = 400.	
0.450	0.010
0.456	0.021
0.463	0.042
0.470	0.073
0.478	0.114
0.486	0.178
0.495	0.259
0.504	0.365
0.515	0.454
0.527	0.497
0.543	0.528
0.556	0.543
0.570	0.548
0.585	0.555
0.602	0.567
0.621	0.570
CURVE 39(CONT.)*	
0.642	0.577
0.664	0.581
0.690	0.592
0.721	0.592
0.758	0.585
CURVE 40*	
T = 450.	
0.456	0.010
0.463	0.022
0.470	0.051
0.478	0.081
0.486	0.135
0.495	0.218
0.505	0.316
0.515	0.412
0.527	0.471
0.543	0.521
0.664	0.574
0.691	0.583
0.722	0.583
0.757	0.559
CURVE 41*	
T = 499.	
0.463	0.011
0.470	0.030
0.478	0.056
0.486	0.094
0.495	0.159
0.504	0.248
0.515	0.354
0.527	0.439
0.544	0.489
0.555	0.513
0.570	0.528
0.585	0.530
0.602	0.536

*NOT SHOWN IN FIGURE.

TABLE 13-15. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 41 (CONT.)*	
0.621	0.534
0.641	0.535
0.664	0.541
0.692	0.546
0.721	0.541
0.758	0.459
CURVE 42*	
T = 499.	
0.470	0.020
0.478	0.035
0.486	0.064
0.495	0.120
0.504	0.192
0.515	0.295
0.527	0.397
0.544	0.455
0.555	0.493
0.570	0.514
0.602	0.525
0.621	0.528
0.641	0.532
0.663	0.531
0.692	0.532
0.722	0.528
0.758	0.507
CURVE 43*	
T = 601.	
0.470	0.009
0.478	0.021
0.486	0.038
0.495	0.077
0.505	0.141
0.515	0.229
0.527	0.337
0.544	0.419
0.555	0.471

λ	τ
CURVE 43 (CONT.)*	
0.570	0.502
0.602	0.533
0.621	0.532
0.641	0.529
0.663	0.529
0.692	0.522
0.723	0.517
0.759	0.498
CURVE 44*	
T = 652.	
0.479	0.011
0.486	0.022
0.495	0.050
0.505	0.106
0.516	0.185
0.528	0.291
0.544	0.390
0.555	0.450
0.570	0.494
0.585	0.521
0.622	0.541
0.642	0.544
0.664	0.548
0.692	0.542
0.723	0.534
0.758	0.517
CURVE 45*	
T = 700.	
0.478	0.006
0.486	0.013
0.495	0.034
0.505	0.067
0.515	0.132
0.527	0.231
0.544	0.342
0.555	0.425

λ	τ
CURVE 45 (CONT.)*	
0.570	0.483
0.585	0.508
0.602	0.533
0.621	0.540
0.641	0.545
0.664	0.547
0.692	0.552
0.722	0.548
0.757	0.530
CURVE 46	
T = 293.	
2.00	0.542
2.12	0.542
2.20	0.497
2.33	0.468
2.61	0.477
2.83	0.477
2.98	0.429
3.30	0.433
3.39	0.433
3.62	0.433
3.78	0.453
4.15	0.450
4.36	0.461
4.60	0.440
5.17	0.429
5.99	0.423
6.19	0.395
6.83	0.405
7.27	0.395
7.60	0.397
8.04	0.389
8.35	0.397
9.03	0.381
9.26	0.404
9.41	0.515
9.55	0.615
9.71	0.542

λ	τ
CURVE 46 (CONT.)	
10.03	0.431
10.68	0.351
11.43	0.289
11.80	0.257
12.45	0.257
12.91	0.281
13.49	0.295
13.99	0.296
14.68	0.319
15.34	0.350
15.70	0.395
16.00	0.409
CURVE 47*	
T = 293.	
0.141	0.026
0.147	0.057
0.153	0.079
0.157	0.112
0.160	0.112
0.167	0.164
0.174	0.215
0.178	0.238
0.183	0.258
0.188	0.268
CURVE 48*	
T = 293.	
0.141	0.027
0.147	0.063
0.155	0.120
0.158	0.152
0.160	0.138
0.162	0.171
0.165	0.206
0.171	0.236
0.175	0.263
0.188	0.283

λ	τ
CURVE 49*	
T = 293.	
0.142	0.0
0.149	0.043
0.157	0.090
0.160	0.077
0.166	0.120
0.171	0.148
0.174	0.172
0.180	0.193
0.184	0.208
0.188	0.226
CURVE 50*	
T = 293.	
0.142	0.0
0.148	0.059
0.155	0.114
0.157	0.129
0.160	0.116
0.162	0.137
0.164	0.168
0.169	0.195
0.178	0.223
0.188	0.249
CURVE 51*	
T = 293.	
0.141	0.153
0.150	0.215
0.153	0.248
0.155	0.282
0.159	0.215
0.166	0.245
0.168	0.291
0.169	0.320
0.172	0.342
0.177	0.351

λ	τ
CURVE 52	
T = 293.	
0.399	0.026
0.417	0.184
0.427	0.271
0.495	0.264
0.626	0.237
0.648	0.226
0.800	0.224
0.898	0.244
1.013	0.277
1.357	0.434
CURVE 53	
T = 293.	
0.483	0.026
0.518	0.053
0.554	0.083
0.603	0.136
0.699	0.148
0.755	0.161
0.798	0.184
0.898	0.305
0.951	0.376
1.345	0.584
CURVE 54	
T = 293.	
0.427	0.271
0.506	0.297
0.746	0.254
0.800	0.260
0.953	0.304
1.024	0.337
1.357	0.434

*NOT SHOWN IN FIGURE.

TABLE 13-15. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON CARBIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 55	
T = 293.	
0.452	0.123
0.499	0.210
0.606	0.311
0.741	0.351
0.803	0.360
0.849	0.382
0.933	0.407
0.956	0.439
1.014	0.465
1.345	0.513
CURVE 56*	
T = 293.	
0.400	0.0
0.400	0.144
0.408	0.170
0.418	0.186
0.430	0.194
0.449	0.194
0.479	0.189
0.528	0.165
0.580	0.154
0.645	0.141
0.703	0.131
0.756	0.125
0.833	0.125
0.880	0.132
0.929	0.142
0.973	0.150
0.996	0.161
1.022	0.177
CURVE 57*	
T = 293.	
0.399	0.0
0.399	0.138
0.414	0.153

λ	τ
CURVE 57(CONT.)*	
0.449	0.167
0.508	0.167
0.556	0.160
0.616	0.156
0.722	0.152
0.808	0.152
0.859	0.157
0.906	0.169
0.936	0.181
0.965	0.195
0.984	0.206
0.999	0.219
1.014	0.237
CURVE 58	
T = 293.	
15.1	0.219
15.2	0.236
15.4	0.278
15.6	0.319
15.7	0.329
15.8	0.326
15.9	0.322
16.4	0.349
16.6	0.366
16.7	0.366
16.9	0.381
17.2	0.395
17.8	0.408
18.1	0.414
18.5	0.414
18.8	0.406
19.0	0.397
19.2	0.384
19.4	0.359
19.5	0.306
19.6	0.245
19.7	0.095
19.8	0.072

λ	τ
CURVE 58(CONT.)	
19.9	0.093
20.0	0.382
20.2	0.399
20.5	0.413
20.8	0.421
21.3	0.425
CURVE 59	
T = 293.	
14.8	0.201
15.3	0.212
15.8	0.240
16.1	0.249
17.0	0.260
18.0	0.269
18.8	0.274
19.5	0.278
20.0	0.285
20.6	0.295
CURVE 60	
T = 293.	
15.4	0.307
15.5	0.323
15.6	0.344
15.7	0.344
15.8	0.339
16.0	0.339
16.2	0.347
16.3	0.365
16.5	0.386
16.7	0.389
17.0	0.408
17.4	0.424
17.9	0.436
18.4	0.445
19.1	0.449
19.2	0.444

λ	τ
CURVE 60(CONT.)	
19.7	0.257
19.8	0.246
19.9	0.267
20.2	0.402
20.3	0.429
20.5	0.439
CURVE 61	
T = 293.	
15.1	0.341
15.8	0.376
16.3	0.406
16.7	0.419
17.0	0.433
17.7	0.442
18.3	0.448
19.0	0.458
20.0	0.461
21.0	0.466

*NOT SHOWN IN FIGURE.

4.14. Silicon Nitride

Bulk silicon nitride is manufactured by standard metallurgical techniques based on reacting silicon powder with nitrogen at elevated temperatures (above 1573 K). It is used as a hard refractory material in high temperature ceramic applications with a useful service temperature of about 1500 K. It dissociates at about 2200 K. It has been reported that there are two types of crystal structure of silicon nitride, α-Si_3N_4 and β-Si_3N_4, both of which are hexagonal but with different lattice constants in the c-axis [T52257]. Four types of crystructure of Si_3N_4 have also been reported [T29667]. Silicon nitride is a good electrical insulator with reported resistivity of 10^{12} ohm-cm at room temperature and 10^6 ohm-cm at 1300 K. Its thermal expansion coefficient is $2.5 \times 10^{-6}\ K^{-1}$ over the range of 300-1300 K. As a result of this low thermal expansion, its thermal shock resistance is very good so that this bulk material can be used as a high temperature radome material.

Dense silicon nitride is produced by hot pressing and sintering silicon powder compact in a nitrogen atmosphere at high pressure and at a temperature near the melting point of silicon (1687 K). Using this technique, laboratory preparations have resulted in samples of 98% purity.

There is a considerable increase of interest in silicon nitride thin films for microelectronic applications in the recent years. Silicon nitride films can be prepared by several different deposition techniques:

a) Direct nitridation
b) Evaporation
c) Glow discharge (dc and rf)
d) Sputtering (dc, rf, and reactive)
e) Pyrolytic (chemical vapor deposition)

The reactive sputtering and pyrolysis methods have been most frequently utilized. In each of these deposition methods, several parameters can be varied: temperature, flow rate, plasma density, pressure or degree of vacuum, ratio of reactants, or electric field. Prior to deposition, the substrates are usually given a mechanical lap followed by a mechanical or chemical polish. Heat treatment of the film is also utilized.

a. Normal Spectral Emittance (Wavelength Dependence)

There is only one set of data on the normal spectral emittance of Si_3N_4 available. Schatz, Goldberg, Pearson, and Burks [T22272] have measured the emittance for the

sintered specimen with density 1.82 g cm^{-3} at 1023 K. Compared with the theoretical density of 3.43 g cm^{-3}, their specimen has very high porosity. Therefore, based on this measurement only provisional values of normal spectral emittance were reported here which are listed in Table 14-1 and shown in Figure 14-1, and they are slightly lower than the experimental results. The estimated uncertainty of the normal spectral emittance is about ± 30%.

TABLE 14-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

λ	ϵ
SINTERED	
T = 1023	
1.00	0.740
1.25	0.692
1.39	0.687
1.81	0.721
2.00	0.778
2.25	0.789
3.00	0.809
3.46	0.839
3.60	0.835
3.80	0.847
4.00	0.850
4.16	0.851
4.25	0.829
4.50	0.835
5.00	0.850
5.32	0.866
5.91	0.865
6.00	0.858
6.21	0.866
6.34	0.855
6.50	0.872
7.00	0.868
7.50	0.890
7.68	0.896
8.00	0.896
8.17	0.854
8.55	0.873
8.71	0.863
9.00	0.843
9.25	0.825
9.50	0.808
9.76	0.805
10.0	0.814
10.3	0.809
10.5	0.793
10.6	0.810
10.9	0.797
11.0	0.799
11.3	0.798
SINTERED	
T = 1023 (CONT.)	
11.5	0.804
11.8	0.804
12.0	0.815
12.2	0.833
12.5	0.833
12.6	0.836
12.9	0.832
13.0	0.833
13.5	0.841
14.0	0.841
14.3	0.847
14.5	0.841
14.8	0.844
15.0	0.864

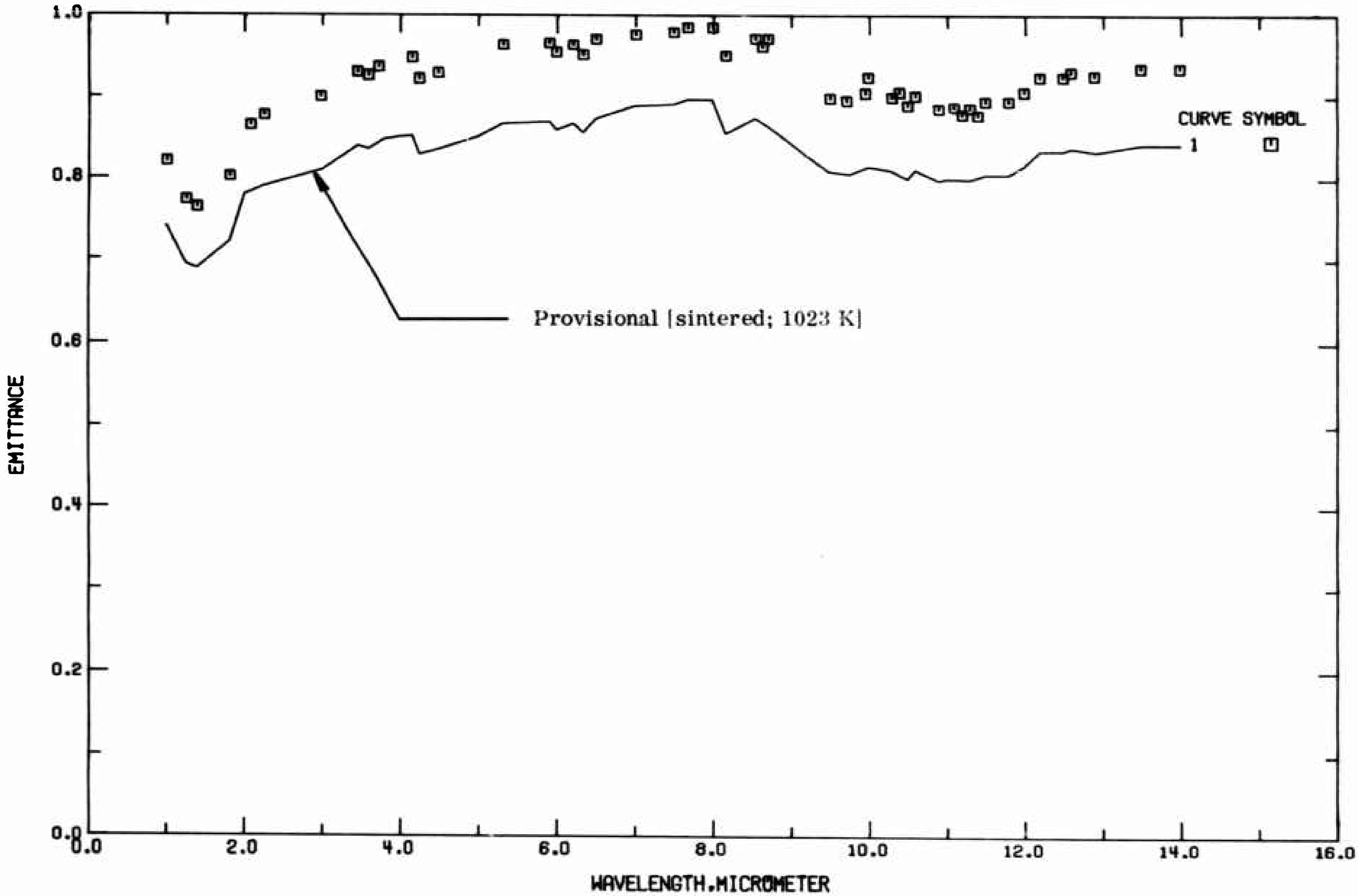


FIGURE 14-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE).

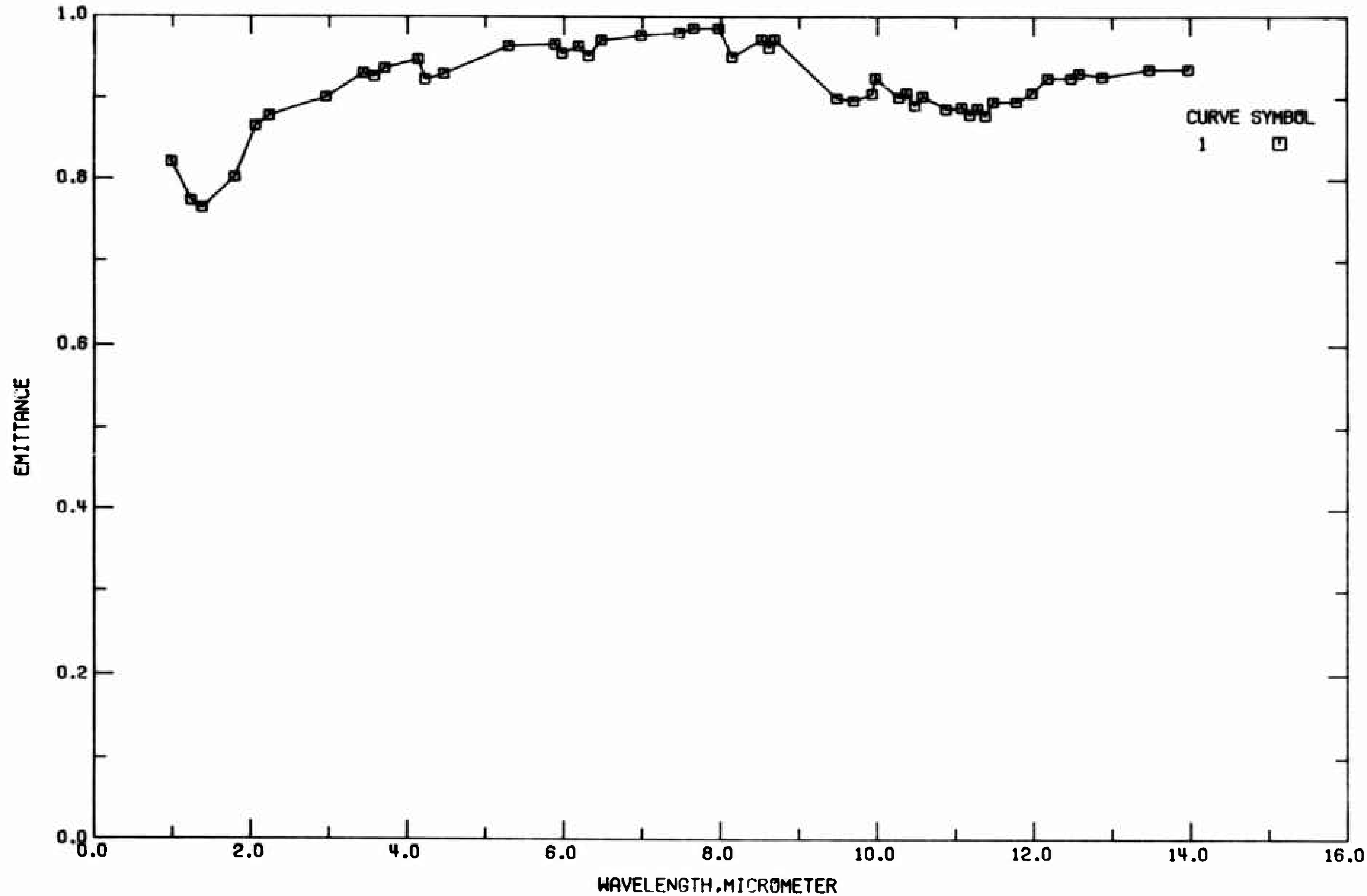


FIGURE 14-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE).

TABLE 14-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF SILICON NITRIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T22272	Schatz, E.A., Goldberg, D.M., Pearson, E.A., and Burks, T.L.	1963	1-15	1023		Sintered at 1673 K for 2 hr (settler material Si_3N_4); density 1.82 g cm^{-3}; $\theta' \sim 0°$.

TABLE 14-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε
CURVE 1		CURVE 1 (CONT.)	
T = 1023.		11.4	0.877
1.00	0.820	11.5	0.894
1.25	0.772	11.8	0.894
1.39	0.763	12.0	0.905
1.81	0.861	12.2	0.923
2.08	0.864	12.5	0.923
2.25	0.876	12.6	0.929
2.98	0.899	12.9	0.925
3.46	0.929	13.5	0.934
3.60	0.925	14.0	0.934
3.73	0.935	14.3	0.941
4.16	0.946	14.5	0.934
4.25	0.921	14.8	0.938
4.49	0.928	15.0	0.960
5.32	0.962		
5.91	0.964		
6.00	0.953		
6.21	0.962		
6.34	0.950		
6.50	0.969		
7.01	0.975		
7.50	0.978		
7.68	0.984		
8.00	0.984		
8.17	0.949		
8.55	0.970		
8.64	0.960		
8.71	0.970		
9.51	0.898		
9.72	0.895		
9.96	0.904		
10.0	0.923		
10.3	0.899		
10.4	0.905		
10.5	0.889		
10.6	0.901		
10.9	0.885		
11.1	0.887		
11.2	0.878		
11.3	0.886		

b. Normal Spectral Reflectance (Wavelength Dependence)

There are ten sets of experimental data available for the wavelength dependence of the normal spectral reflectance of silicon nitride as listed in Table 14-6 and shown in Figure 14-4. Specimen characterization and measurement information for the data are given in Table 14-5. Schatz, Goldberg, Pearson, and Burks [T22272] measured the normal spectral reflectance for sintered samples in the 0.23-2.65 μm wavelength region while Schatz [T34908] and Schatz, Alvarez, Counts, and Hepplu [T35840] measured the normal spectral reflectance of compacted powder specimen with compaction pressure from 2350 psi to 70 500 psi in the 0.23-2.65 μm region. Schatz, Alverez, Burkes, Counts, and Dunkerley [T33974] measured the reflectance for the specimen pressed at 21 000 psi in the 1.0-15 μm wavelength region at 373 K. It is observed that for the sintered specimen, the reflectance data values were lower than those of the pressed samples. One possible explanation is that it has lower density (1.82 g cm^{-3}), hence a lower reflectance value. Since all the measurements were made by the same research group, only one set of data is available for the longer wavelength region. As a consequence, only provisional values are justified. The provisional values are for the pressed specimen at 373 K which are listed in Table 14-4 and shown in Figure 14-3. The estimated uncertainty for the provisional values is within ±30%.

TABLE 14-4. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ
COMPACTED POWDER T = 373		COMPACTED POWDER T = 373 (CONT.)	
0.23	0.225	13.50	0.301
0.30	0.324	14.00	0.301
0.40	0.358	14.50	0.301
0.50	0.368	15.00	0.296
0.60	0.393		
0.75	0.418		
0.80	0.425		
0.87	0.441		
1.00	0.429		
1.25	0.405		
1.50	0.379		
1.75	0.347		
2.00	0.315		
2.50	0.290		
2.65	0.270		
2.80	0.240		
3.00	0.241		
3.25	0.241		
3.50	0.237		
3.80	0.233		
4.00	0.231		
4.50	0.225		
5.00	0.200		
5.50	0.183		
6.00	0.192		
6.50	0.195		
7.00	0.200		
7.50	0.200		
8.00	0.195		
8.50	0.204		
9.00	0.254		
9.50	0.278		
10.00	0.297		
10.50	0.310		
11.00	0.309		
11.50	0.303		
12.00	0.307		
12.50	0.302		
13.00	0.306		

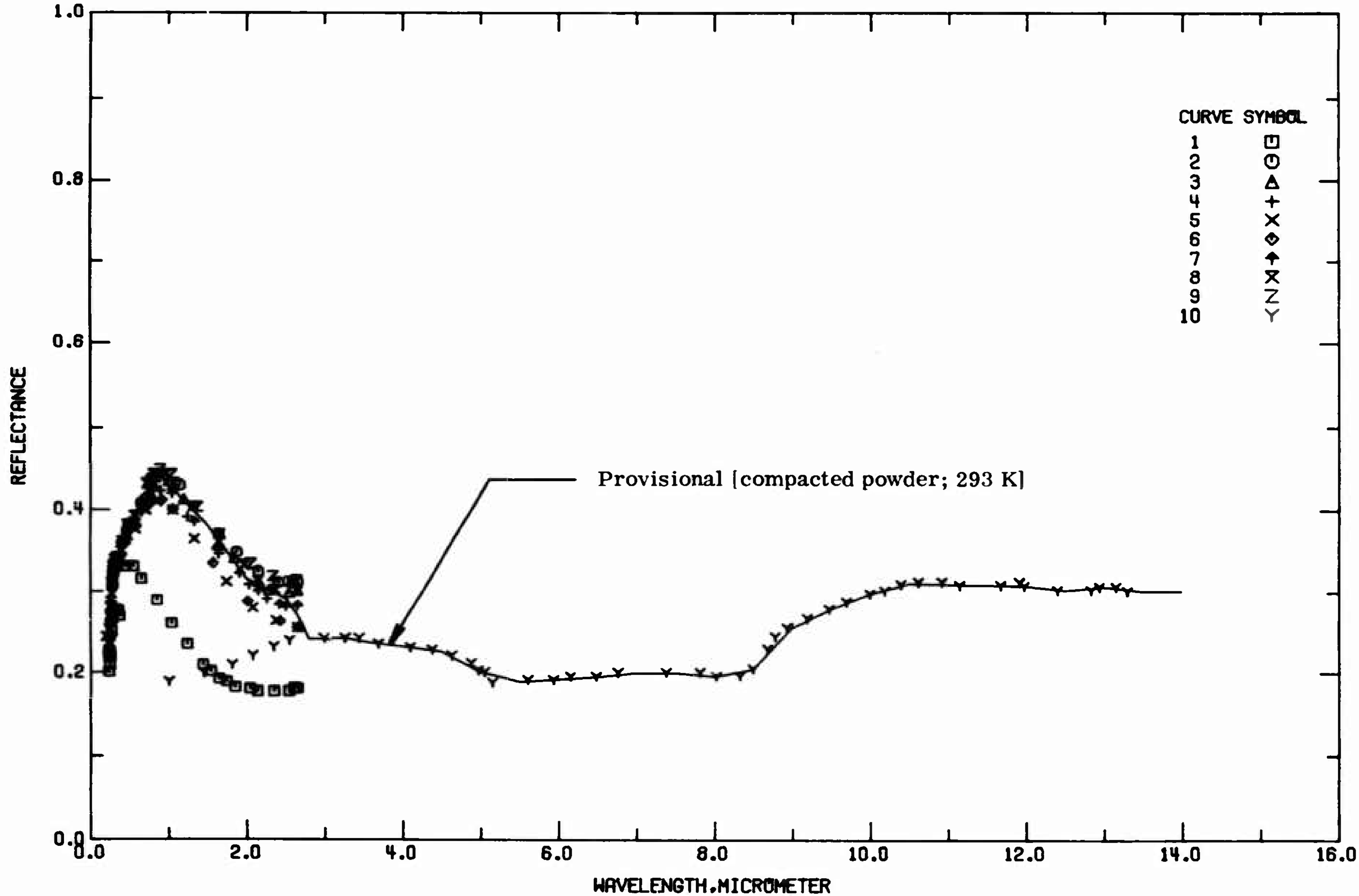


FIGURE 14-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE).

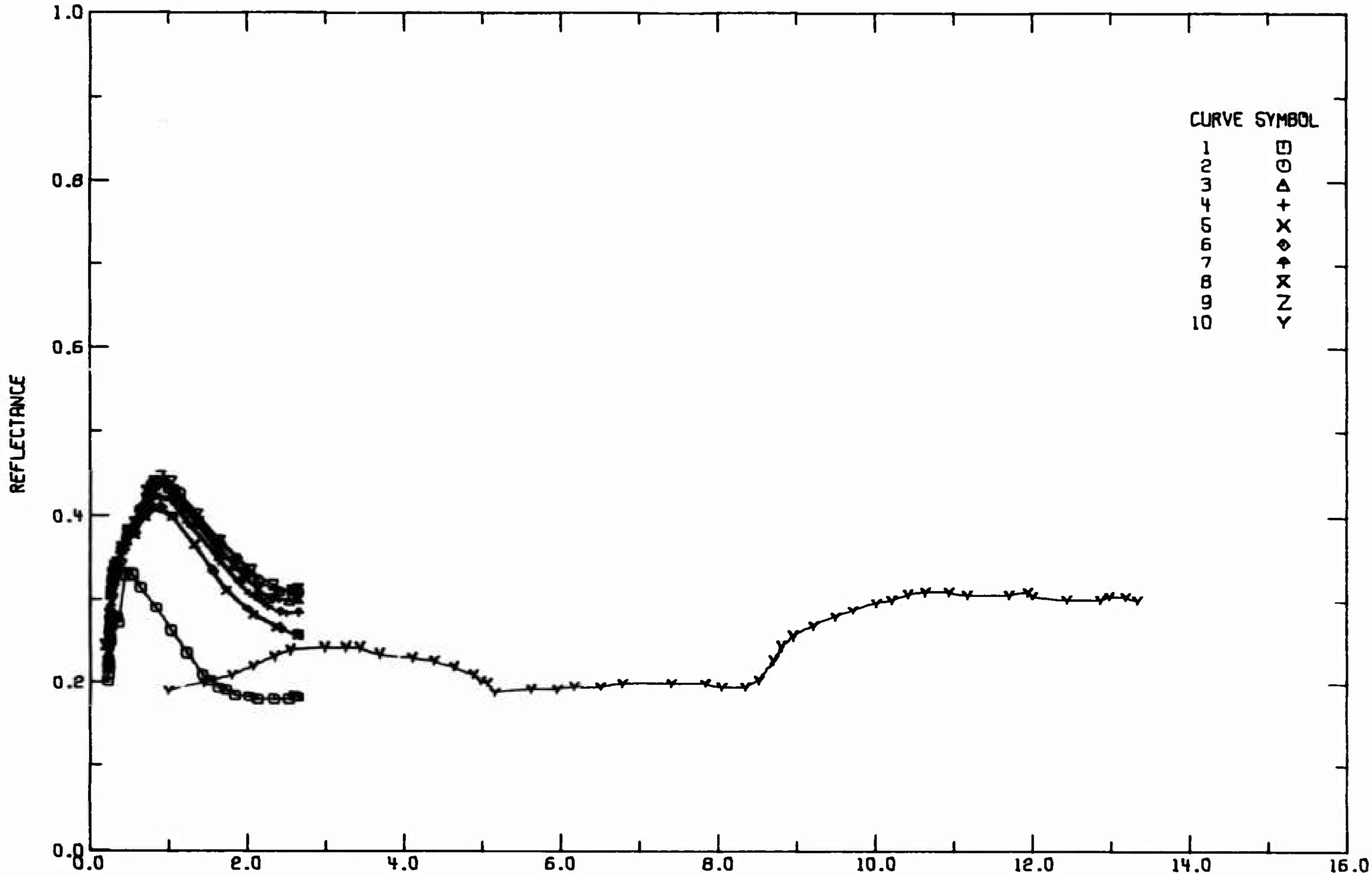


FIGURE 14-4. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE).

TABLE 14-3. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF SILICON NITRIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T22272	Schatz, E.A., Goldberg, D.M., Pearson, E.G., and Burks, T.L.	1963	0.23-2.65	293	No. 106	Sintered at 1673 K for 2 hr; density 1.82 g cm^{-3}; MgO reference standard; data extracted from smooth curve; $\theta=0°$, $\omega'=2\pi$.
2	T34908	Schatz, E.A.	1966	0.23-2.65	293		Compacted Si_3N_4 powder; compaction pressure 2350 psi; measurements will be performed on a Beckman DK-2A Spectroreflectometer U.S. MgO standards; $\theta=0°$, $\omega'=2\pi$.
3	T34908	Schatz, E.A.	1966	0.23-2.65	293		Similar to the above specimen except compaction pressure 11800 psi.
4	T34908	Schatz, E.A.	1966	0.23-2.65	293		Similar to the above specimen except compaction pressure 35300 psi.
5	T34908	Schatz, E.A.	1966	0.23-2.65	293		Similar to the above specimen except compaction pressure 70500 psi.
6	T35840	Schatz, E.A., Alvarez, G.H., Counts, C.H., III, and Hoppke, M.A.	1965	0.23-2.65	298		Specimen was Si_3N_4 powders compacted into stainless steel circular sample holder under compacting pressure 2350 psi; measurements U.S. MgO standard; $\theta=0°$, $\omega'=2\pi$.
7	T35840	Schatz, E.A., et al.	1965	0.23-2.65	298		Similar to the above specimen except compacting pressure 11750 psi.
8	T35840	Schatz, E.A., et al.	1965	0.23-2.65	298		Similar to the above specimen except compacting pressure 35250 psi.
9	T35840	Schatz, E.A., et al.	1965	0.23-2.65	298		Similar to the above specimen except compacting pressure 70500 psi.
10	T33974	Schatz, E.A., Alvarez, G.H., Burks, T.L., Counts, C.R., III, and Dunkerley, F.J.	1964	1-15	373		Pressed Si_3N_4 powder specimen; pressed at 21000 psi; the absolute spectral reflectance are measured by using a blackbody reflectometer apparatus; $\theta=0°$, $\omega'=2\pi$.

TABLE 14-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 298.	
0.230	0.200
0.240	0.209
0.250	0.220
0.266	0.249
0.280	0.265
0.290	0.274
0.300	0.276
0.321	0.276
0.331	0.275
0.350	0.275
0.370	0.268
0.449	0.330
0.550	0.330
0.651	0.315
0.849	0.288
1.04	0.259
1.24	0.234
1.44	0.209
1.54	0.201
1.64	0.192
1.74	0.189
1.85	0.182
2.04	0.180
2.14	0.177
2.35	0.177
2.54	0.177
2.61	0.181
2.65	0.180
CURVE 2	
T = 298.	
0.230	0.220
0.242	0.226
0.255	0.261
0.280	0.307
0.298	0.324
0.315	0.335
0.349	0.343

λ	ρ
CURVE 2 (CONT.)	
0.404	0.357
0.486	0.381
0.646	0.407
0.783	0.437
0.874	0.442
1.14	0.429
1.64	0.367
1.87	0.347
2.15	0.324
2.41	0.311
2.59	0.311
2.65	0.312
CURVE 3	
T = 298.	
0.230	0.219
0.243	0.231
0.260	0.275
0.279	0.312
0.313	0.335
0.349	0.337
0.439	0.362
0.547	0.410
0.821	0.438
1.00	0.434
1.19	0.412
1.64	0.355
1.84	0.340
2.15	0.312
2.28	0.301
2.54	0.298
2.65	0.300
CURVE 4	
T = 298.	
0.230	0.231
0.243	0.241
0.255	0.275

λ	ρ
CURVE 4 (CONT.)	
0.275	0.313
0.287	0.327
0.302	0.330
0.349	0.334
0.450	0.365
0.651	0.396
0.748	0.419
0.891	0.422
1.04	0.419
1.24	0.390
1.64	0.345
2.03	0.308
2.26	0.290
2.50	0.280
2.65	0.281
CURVE 5	
T = 298.	
0.20	0.243
0.242	0.251
0.258	0.281
0.280	0.318
0.288	0.330
0.349	0.333
0.468	0.367
0.571	0.375
0.704	0.399
0.842	0.409
1.05	0.399
1.33	0.363
1.74	0.312
2.08	0.279
2.38	0.263
2.65	0.254
CURVE 6	
T = 298.	
0.230	0.229

λ	ρ
CURVE 6 (CONT.)	
0.242	0.239
0.250	0.257
0.260	0.284
0.270	0.302
0.280	0.316
0.290	0.326
0.309	0.332
0.330	0.336
0.350	0.337
0.399	0.344
0.464	0.370
0.580	0.378
0.714	0.403
0.803	0.411
0.912	0.411
1.05	0.400
1.57	0.334
2.01	0.287
2.43	0.262
2.65	0.254
CURVE 7	
T = 298.	
0.230	0.230
0.235	0.231
0.245	0.243
0.256	0.272
0.264	0.291
0.273	0.307
0.283	0.319
0.292	0.326
0.309	0.331
0.349	0.338
0.391	0.353
0.464	0.375
0.547	0.383
0.649	0.399
0.734	0.417
0.799	0.426

λ	ρ
CURVE 7 (CONT.)	
1.05	0.423
1.33	0.384
1.62	0.351
1.91	0.322
2.15	0.300
2.42	0.283
2.65	0.282
CURVE 8	
T = 298.	
0.230	0.218
0.236	0.221
0.251	0.252
0.262	0.279
0.278	0.310
0.293	0.324
0.308	0.331
0.318	0.338
0.350	0.341
0.411	0.360
0.483	0.381
0.568	0.392
0.721	0.431
0.815	0.442
0.960	0.442
1.06	0.432
1.31	0.403
1.64	0.360
1.97	0.332
2.15	0.313
2.36	0.302
2.65	0.300
CURVE 9	
T = 298.	
0.230	0.218
0.236	0.221
0.251	0.252

λ	ρ
CURVE 9 (CONT.)	
0.262	0.279
0.278	0.310
0.293	0.324
0.308	0.331
0.318	0.338
0.350	0.341
0.411	0.360
0.483	0.381
0.568	0.392
0.721	0.431
0.815	0.442
0.899	0.448
1.04	0.442
1.37	0.403
1.66	0.369
2.06	0.334
2.34	0.319
2.56	0.312
2.65	0.314
CURVE 10	
T = 373.	
1.00	0.188
1.45	0.199
1.81	0.209
2.08	0.220
2.35	0.231
2.55	0.238
2.99	0.241
3.26	0.241
3.44	0.241
3.63	0.234
4.10	0.230
4.38	0.227
4.63	0.220
4.88	0.211
4.97	0.202
5.05	0.200
5.15	0.187

TABLE 14-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 10(CONT.)	
5.61	0.191
5.94	0.191
6.16	0.195
6.49	0.195
6.77	0.200
7.39	0.200
7.82	0.200
8.03	0.195
8.33	0.195
8.55	0.204
8.69	0.228
8.79	0.243
8.94	0.254
9.20	0.266
9.48	0.278
9.70	0.287
10.00	0.297
10.19	0.301
10.40	0.309
10.62	0.312
10.92	0.312
11.15	0.308
11.68	0.308
11.92	0.312
11.98	0.307
12.41	0.302
12.84	0.302
12.95	0.306
13.16	0.306
13.31	0.301
14.15	0.301
14.38	0.304
14.51	0.301
14.87	0.302
15.00	0.296

c. Normal Spectral Absorptance (Wavelength Dependence)

There are four sets of experimental data available for the wavelength dependence of the normal spectral absorptance of silicon nitride as listed in Table 14-9 and shown in Figure 14-5. Specimen characterization and measurement information for the data are given in Table 14-8. Three sets of data are for the thin film specimen coating on silicon substrate and one set of data is for the powder specimen. All the measurements were performed at room temperature. They all show a broad peak of absorption with the maximum near the 10-12 μm region. However, there is no information on the thickness of the sample and substrate which is essentially for the absorptance value. Therefore, we cannot make any recommended values for the absorptance on coating specimens. According to Kirchhoff's law, the absorptance is equal to the emittance, $\alpha = \epsilon$. Therefore, the provisional values on the normal spectral absorptance for sintered specimens at 1023 K were obtained which are listed in Table 14-7 and shown in Figure 14-6. The estimated uncertainty is about ±30%.

TABLE 14-7. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α
SINTERED		SINTERED	
T = 1023		T = 1023 (CONT.)	
1.00	0.740	11.5	0.804
1.25	0.692	11.8	0.804
1.39	0.687	12.0	0.815
1.81	0.721	12.2	0.833
2.00	0.778	12.5	0.833
2.25	0.789	12.6	0.836
3.00	0.809	12.9	0.832
3.46	0.839	13.0	0.833
3.60	0.835	13.5	0.841
3.80	0.847	14.0	0.841
4.00	0.850	14.3	0.847
4.16	0.851	14.5	0.841
4.25	0.829	14.8	0.844
4.50	0.835	15.0	0.864
5.00	0.850		
5.32	0.866		
5.91	0.868		
6.00	0.858		
6.21	0.866		
6.34	0.855		
6.50	0.872		
7.00	0.888		
7.50	0.890		
7.68	0.896		
8.00	0.896		
8.17	0.854		
8.55	0.873		
8.71	0.863		
9.00	0.843		
9.25	0.825		
9.50	0.808		
9.76	0.805		
10.0	0.814		
10.3	0.809		
10.5	0.799		
10.6	0.810		
10.9	0.797		
11.0	0.799		
11.3	0.798		

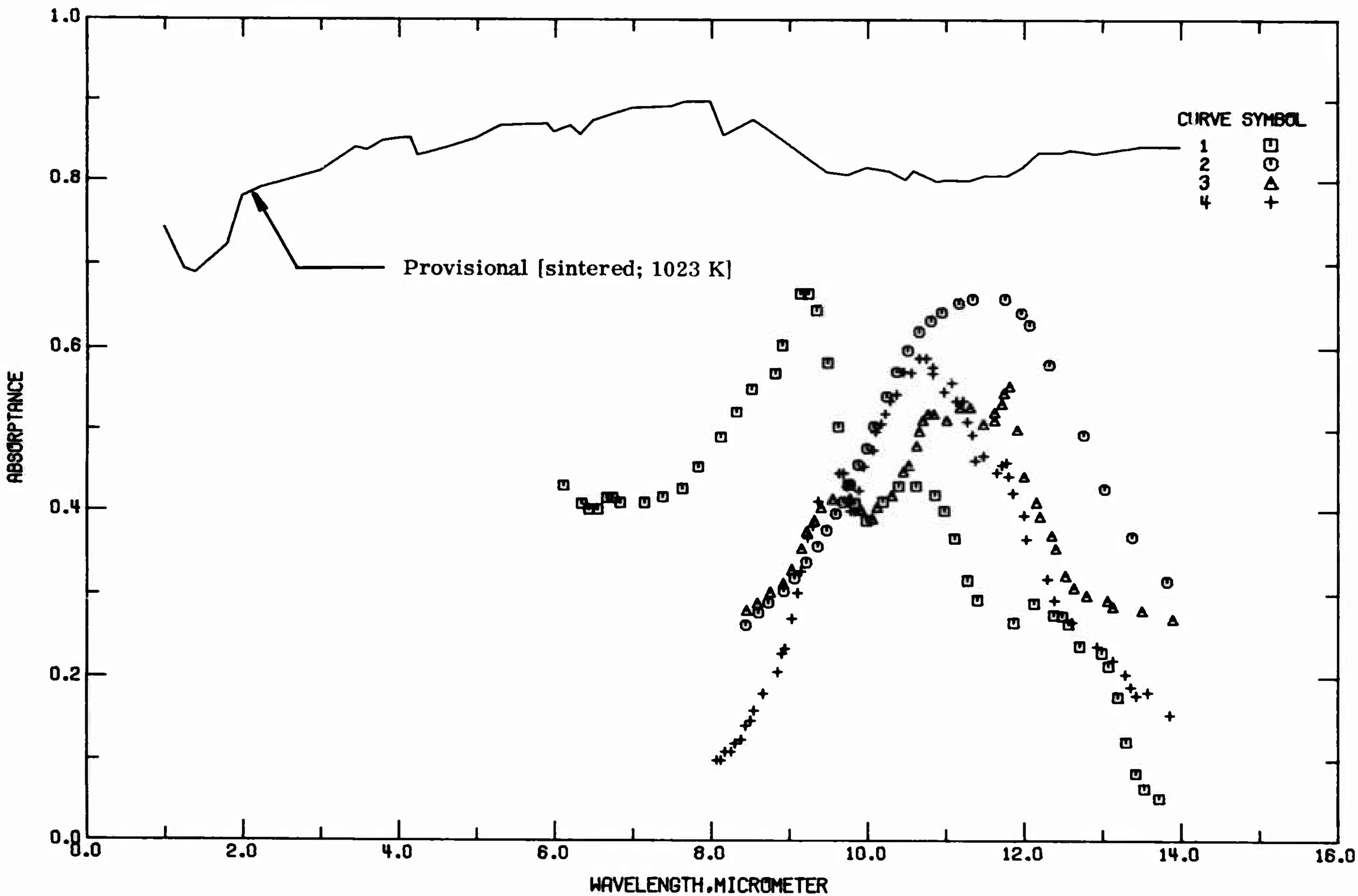


FIGURE 14-5. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE).

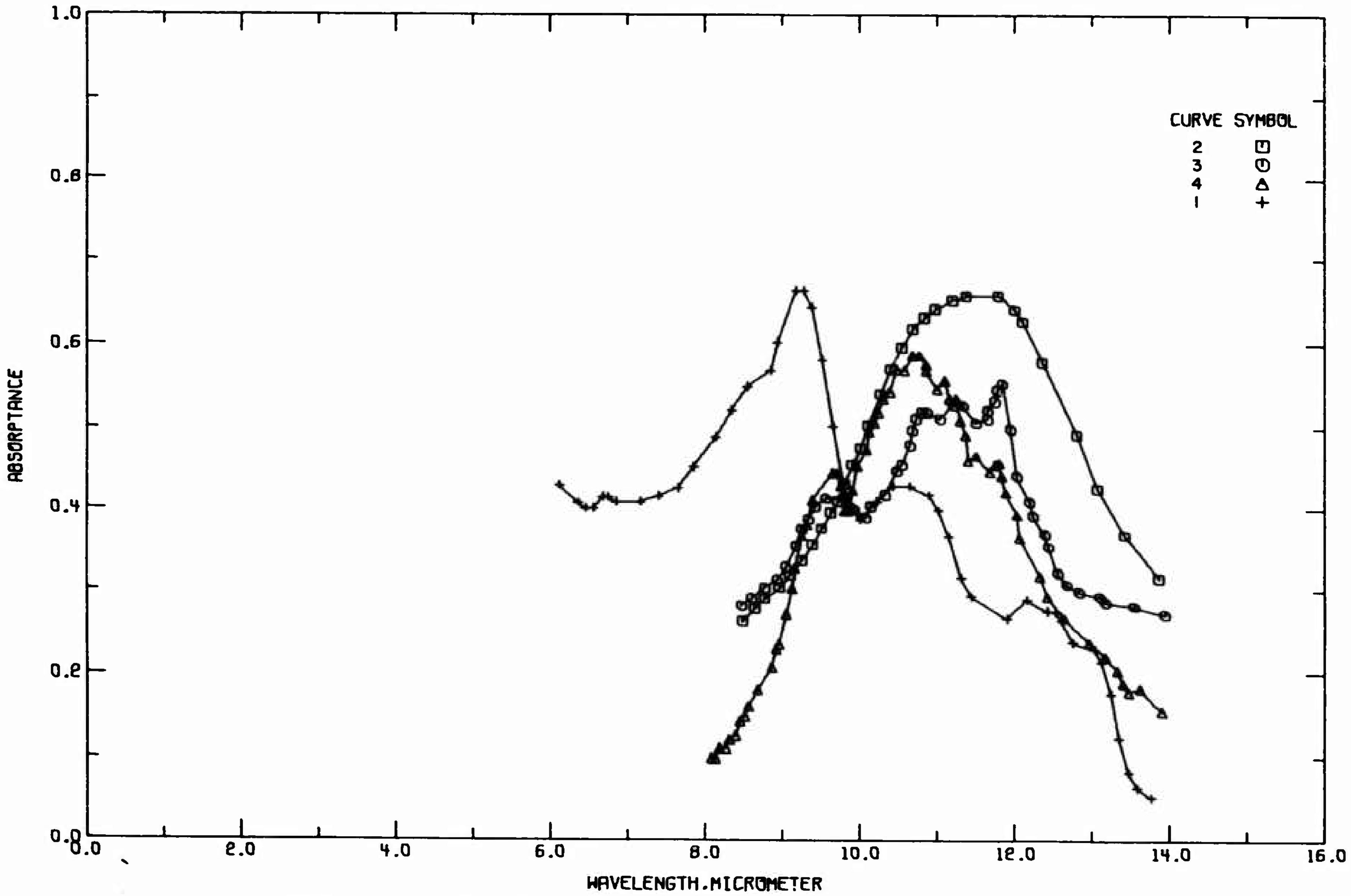


FIGURE 14-6. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE).

TABLE 14-8. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF SILICON NITRIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	E46853	Bartnitskii, I.N., Ayunoo, B.M., and Kuryalva, R.G.	1970	6-25	~293	Si_3N_4 on Si	Silicon nitride film was deposited on silicon by electrolysis in liquid ammonia with a constant voltage applied to the cell; the film resistivity was of the order of 10^9 Ω-cm; a UR-10 spectrograph was used to obtain the absorption spectra.
2	E34318	Badcock, F.R., Lamb, D.R., and Wood, S.S.	1967	8.5-14.5	~293		Silicon nitride film was deposited on silicon substrate by reacting together ammonia and silane or trichlorosilance vapor; data were extracted from the smooth curve; $\theta \sim 0°$.
3	E34318	Badcock, F.R., et al.	1967	8.5-14.5	~293		Silicon nitride crystalline film was grown thermally at 1300 C in ammonia at atm pressure; data were extracted from the smooth curve; $\theta \sim 0°$.
4	E34318	Badcock, F.R., et al.	1967	8.5-14.5	~293		Silicon nitride powder; data were extracted from the smooth curve; $\theta \sim 0°$.

TABLE 14-9. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α)

λ	α
CURVE 1	
T = 293.	
6.11	0.429
6.35	0.407
6.44	0.403
6.55	0.400
6.67	0.414
6.74	0.414
6.64	0.408
7.15	0.408
7.39	0.415
7.64	0.425
7.84	0.452
8.13	0.489
9.33	0.521
6.53	0.549
8.83	0.568
8.92	0.602
9.16	0.663
9.26	0.663
9.36	0.643
9.50	0.581
9.63	0.502
9.77	0.430
9.84	0.407
9.99	0.386
10.20	0.409
10.41	0.428
10.63	0.428
10.87	0.417
10.99	0.398
11.12	0.365
11.29	0.315
11.42	0.292
11.88	0.265
12.14	0.285
12.39	0.274
12.50	0.273
12.58	0.263
12.72	0.237
13.00	0.229

λ	α
CURVE	1(CONT.)
13.09	0.213
13.21	0.176
13.32	0.122
13.44	0.083
13.55	0.064
13.74	0.052
14.10	0.052
14.31	0.035
14.60	0.020
14.84	0.020
15.04	0.030
15.20	0.065
15.31	0.225
15.41	0.303
15.60	0.405
15.75	0.442
16.00	0.468
16.16	0.323
16.29	0.223
16.31	0.157
16.45	0.114
16.61	0.082
16.92	0.064
17.36	0.064
17.86	0.032
18.49	0.006
19.16	0.011
20.28	0.045
21.65	0.109
22.62	0.109
23.31	0.095
23.81	0.060
24.27	0.026
24.81	0.012
25.38	0.051
25.77	0.104
25.97	0.181

λ	α
CURVE 2	
T = 293.	
8.45	0.262
8.61	0.277
8.73	0.289
8.93	0.303
9.07	0.318
9.22	0.336
9.36	0.355
9.48	0.375
9.60	0.395
9.69	0.409
9.78	0.431
9.88	0.455
9.99	0.475
10.08	0.503
10.25	0.540
10.37	0.570
10.52	0.596
10.66	0.618
10.81	0.631
10.95	0.641
11.17	0.652
11.35	0.657
11.76	0.657
11.98	0.640
12.08	0.626
12.33	0.579
12.77	0.492
13.04	0.425
13.39	0.367
13.83	0.314
CURVE 3	
T = 293.	
8.45	0.280
8.59	0.289
8.76	0.302
8.92	0.312
9.03	0.328

λ	α
CURVE	3(CONT.)
9.16	0.353
9.23	0.374
9.32	0.387
9.41	0.403
9.55	0.413
9.78	0.413
9.78	0.413
9.91	0.400
10.06	0.389
10.12	0.403
10.31	0.417
10.46	0.447
10.53	0.455
10.63	0.479
10.66	0.497
10.71	0.511
10.78	0.519
10.85	0.519
11.01	0.511
11.19	0.527
11.31	0.527
11.48	0.506
11.63	0.511
11.63	0.521
11.72	0.532
11.75	0.545
11.82	0.553
11.92	0.499
12.00	0.441
12.17	0.409
12.21	0.392
12.36	0.369
12.41	0.353
12.53	0.321
12.64	0.307
12.80	0.298
13.07	0.292
13.14	0.285
13.51	0.280
13.91	0.270

λ	α
CURVE	3(CONT.)
14.12	0.257
14.37	0.255
14.58	0.255
14.77	0.252
CURVE 4	
T = 293.	
8.07	0.099
8.12	0.099
8.18	0.110
8.26	0.110
8.31	0.120
8.38	0.125
8.44	0.142
8.50	0.148
8.55	0.160
8.67	0.180
8.85	0.206
8.90	0.228
8.94	0.234
9.03	0.270
9.11	0.301
9.15	0.326
9.23	0.366
9.30	0.380
9.37	0.410
9.63	0.445
9.69	0.445
9.74	0.428
9.78	0.398
9.83	0.398
9.89	0.423
9.95	0.453
10.07	0.473
10.10	0.496
10.17	0.506
10.22	0.519
10.29	0.535
10.37	0.543

λ	α
CURVE	4(CONT.)
10.46	0.570
10.56	0.569
10.66	0.587
10.75	0.587
10.83	0.576
10.83	0.568
10.98	0.546
11.07	0.557
11.14	0.535
11.22	0.535
11.27	0.509
11.34	0.492
11.38	0.460
11.48	0.466
11.66	0.446
11.72	0.455
11.78	0.458
11.81	0.441
11.86	0.420
12.00	0.393
12.03	0.364
12.30	0.317
12.39	0.292
12.61	0.266
12.94	0.237
13.14	0.220
13.30	0.203
13.37	0.188
13.44	0.178
13.59	0.182
13.87	0.155
14.18	0.134
14.49	0.121
14.64	0.113

d. Normal Spectral Transmittance (Wavelength Dependence)

There are 33 sets of experimental data available for the wavelength dependence of the normal spectral transmittance of silicon nitride as listed in Table 14-12 and shown in Figure 14-8 for the thin film coatings and Figure 14-9 for the powder specimens. Specimen characterization and measurement information are given in Table 14-11. All the measurements were performed at room temperature (~293 K) and a broad absorption peak due to Si-N has a maximum near 11.4 μm.

Silicon, germanium, molybdenum, graphite, gallium arsenide, graphite, and potassium chloride were used as the coating substrate. Fifteen sets of experimental data were measured for the transmittance of thin Si_3N_4 film coating on silicon substrates. However, few authors have reported the thickness of the film and substrate. The various deposition techniques for preparation of the thin films also affect the transmittance. The silicon nitride film was also used as an antireflection coating for silicon and the maximum of transmission was dependent on the thickness of the coating by the well-known square-root condition for quarter-wave films as follows:

$$4n_1 d\lambda_0^{-1} = 2m + 1; \; m = 0, 1, 2, 3, \ldots.. \tag{14-1}$$

$$R_{min} \approx \left(\frac{n_2 - n_1^2}{n_2 + n_1^2}\right) << 1 \text{ for } n_1^2 \approx n_2 \tag{14-2}$$

where d is the coating thickness, λ_0 the free space wavelength, R_{min} the minimum intensity reflectance, and n_1 and n_2 are the refractive indices of the coating and substrate, respectively. Therefore, as a consequence of these difficulties, only the provisional values for a 0.5 μm thick silicon nitride film deposited on both sides of a 250 μm thick silicon substrate by the reactive sputtering technique at room temperature are presented. The estimated uncertainty is within ±30%.

TABLE 14-10. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ
COATING SI SUBSTRATE T = 293		COATING SI SUBSTRATE T = 293 (CONT.)	
1.00	0.359	7.50	0.592
1.08	0.446	8.00	0.557
1.16	0.780	8.50	0.413
1.19	0.854	9.00	0.282
1.24	0.950	9.70	0.241
1.26	0.976	10.00	0.172
1.30	0.999	10.50	0.128
1.34	0.973	11.00	0.110
1.40	0.925	11.40	0.097
1.44	0.846	11.60	0.098
1.50	0.757	12.00	0.098
1.57	0.563	12.35	0.109
1.62	0.625	13.03	0.118
1.66	0.594	13.50	0.133
1.73	0.565	14.00	0.180
1.78	0.546	14.50	0.210
1.87	0.535	15.00	0.243
1.93	0.536		
2.00	0.542		
2.10	0.562		
2.29	0.611		
2.39	0.645		
2.57	0.723		
2.80	0.835		
3.00	0.897		
3.20	0.928		
3.50	0.983		
3.65	0.994		
3.80	0.993		
4.00	0.981		
4.25	0.962		
4.50	0.938		
4.75	0.895		
5.00	0.856		
5.25	0.823		
5.50	0.771		
6.00	0.722		
6.40	0.665		
7.00	0.612		

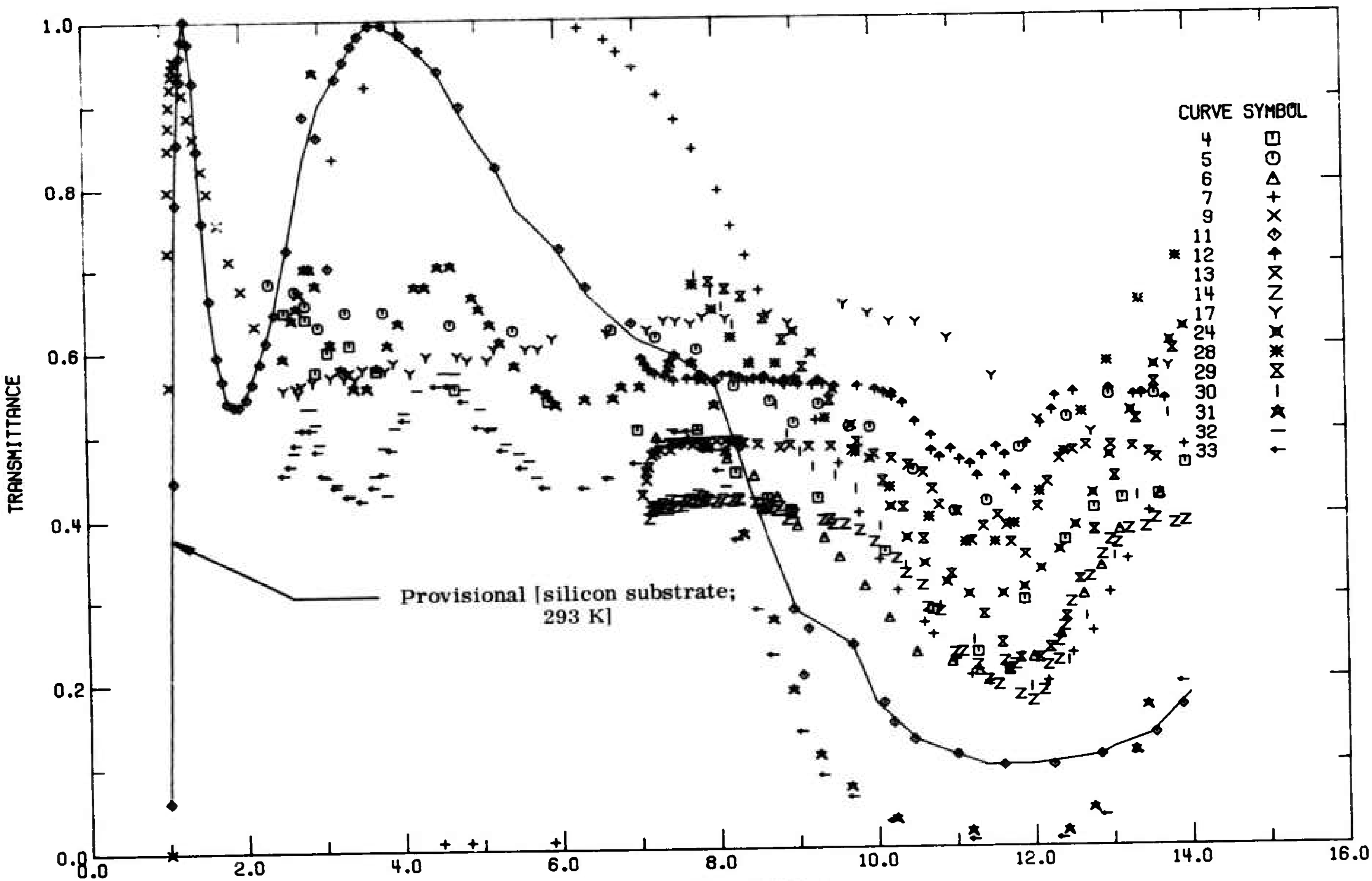


FIGURE 14-7. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE COATINGS (WAVELENGTH DEPENDENCE).

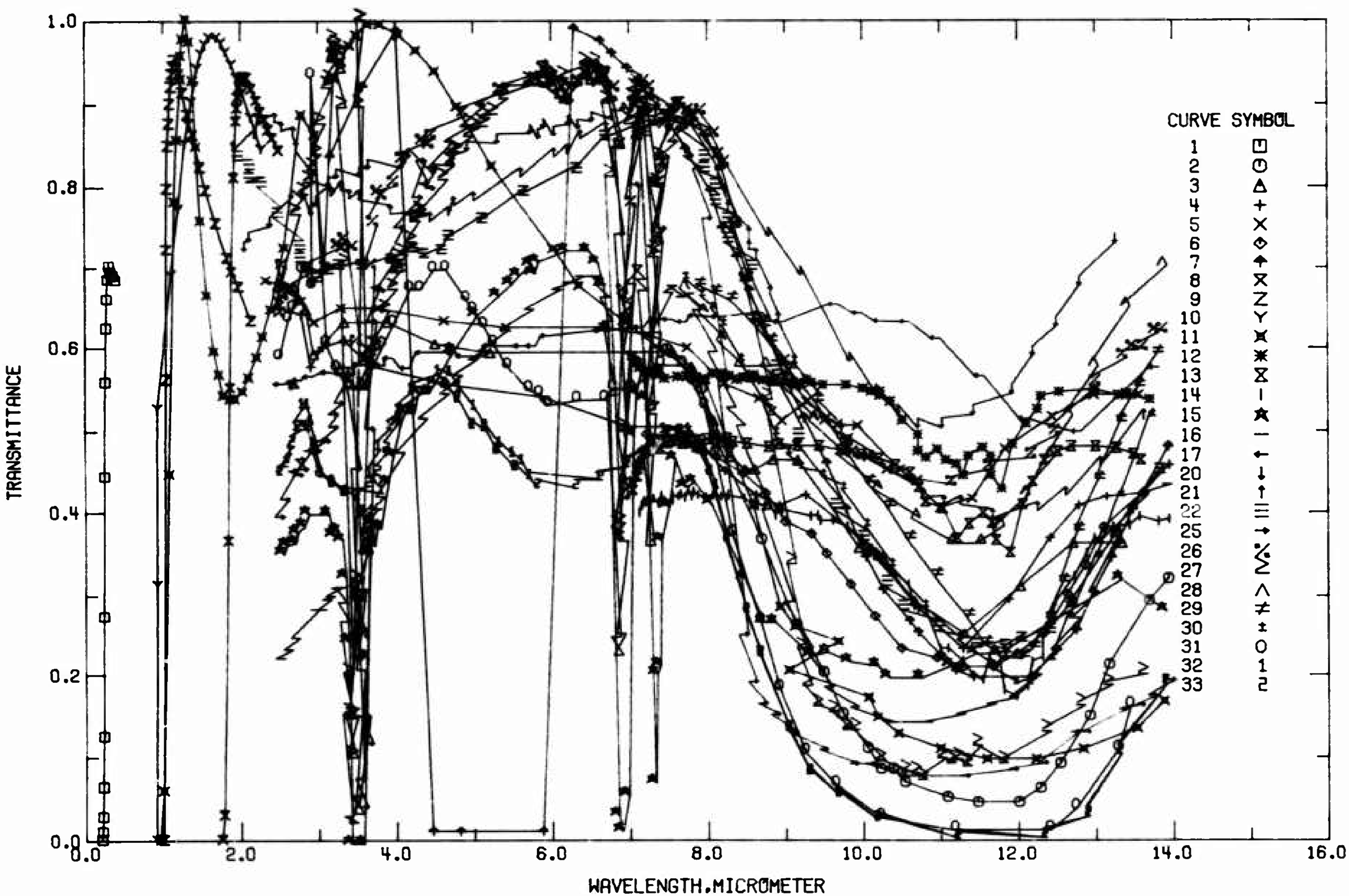


FIGURE 14-8. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE COATINGS (WAVELENGTH DEPENDENCE).

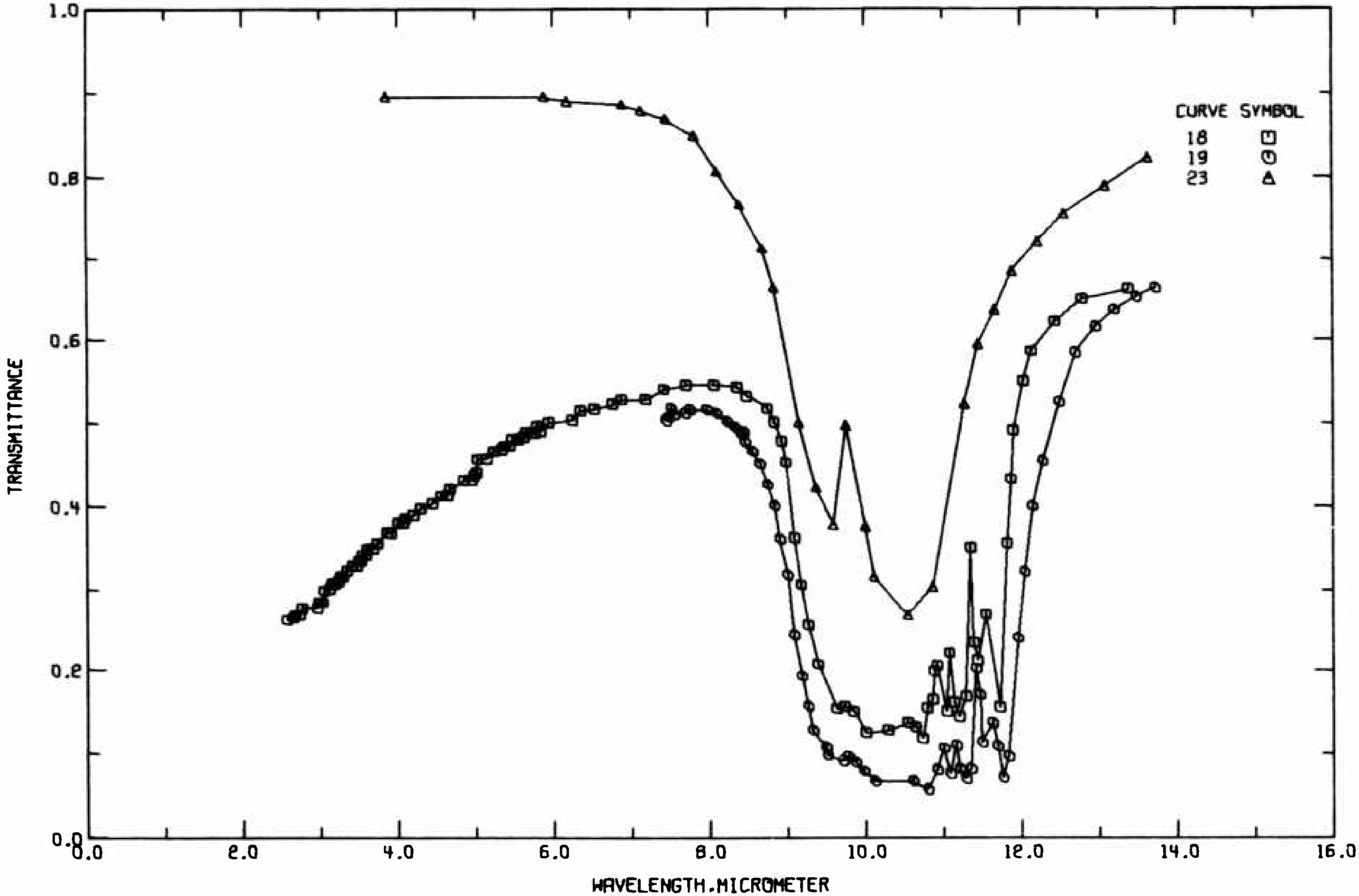


FIGURE 14-9. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE POWDERS (WAVELENGTH DEPENDENCE).

TABLE 14-11. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T45177	Bean, K.E., Glein, P.S., Yeakly, R.L., and Runyan, W.R.	1967	0.2–0.4	293		Si_3N_4 film was deposited on fused silica substrate; index of refraction 2.0; no absorption band between 0.4 and 8 μ; $\theta \sim 0°$.
2	T45177	Bean, K.E., et al.	1967	8–24	293		Similar to the above specimen.
3	T45954	Seki, H. and Moriyana, K.	1967	2.5–16	293		Si_3N_4 film was deposited on GaAs substrate by reacting $SiCl_4$ and NH_3 in N_2 atm at 823 K; $\theta \sim 0°$.
4	T45954	Seki, H. and Moriyana, K.	1967	2.5–16	293		Similar to the above specimen except deposited on Si substrate by reacting $SiCl_4$ and NH_3 in N_2 atm at 823 K.
5	T45954	Seki, H. and Moriyana, K.	1967	2.5–16	293		Similar to the above specimen except at 723 K.
6	T48136	Sugano, T., Hirai, K., Kuroiwa, K., and Itoh, K.	1968	7–12	293		Si_3N_4 film was deposited on Si substrate by gas phase reaction of SiH_4 and NH_3, using N_2 as carrier gas at 1123 K; $\theta \sim 0°$.
7	T52872	Nuttal, R., Rowbotham, C., and Eastwood, E.	1967	3–15	293		1 μm thickness Si_3N_4 films were deposited on 10 Ω cm N-type Si substrate at 1273 K by thermal reaction of NH_3 with SiH_4, $SiCl_4$, or $SiBr_4$; $\theta \sim 0°$.
8	T61411	Laff, R.A.	1971	1.8–2.6	293		0.245 μm film of silicon nitride was coated on both sides of Ge window (3840 μm thickness) by rf-diode reactive sputtering technique; $\theta \sim 0°$.
9	T61411	Laff, R.A.	1971	1.0–2.2	293		Similar to the above specimen except 0.140 μm film of silicon nitride was coated on both side of Si window (750 μm thickness).
10	T61411	Laff, R.A.	1971	0.9–2.3	293		Similar to the above specimen except 0.220 μm film of silicon nitride was coated on both side of GaAs window (100 μm thickness).
11	T61411	Laff, R.A.	1971	1–15	293		Similar to the above specimen except 0.505 μm film of silicon nitride was coated on both side of Si window (250 μm thickness).
12	T65344	Kamchatka, M.I., and Ormont, B.F.	1971	6.67–20	293		Polycrystalline Si_3N_4 was coated on p-type Si single crystal substrate by reaction of ammonia with the silicon substrate at 1623 K for 18 min; $\theta \sim 0°$.
13	T65344	Kamchatka, M.I., and Ormont, B.F.	1971	6.67–20	293		Similar to the above specimen except it was prepared for 60 min.
14	T65344	Kamchatka, M.I., and Ormont, B.F.	1971	6.67–20	293		Similar to the above specimen except it was prepared for 180 min.
15	T44942	Berg, D., Lewis, D.W., Dakin, T.W., Sestrich, D.E., and Epposito, J.N.	1966	2.5–50	293		Si_3N_4 film was deposited on graphite substrate by pyrolysis of SiF_4 and $2NH_3$; $\theta \sim 0°$.
16	T44942	Berg, D., et al.	1966	2.5–50	293		Similar to the above specimen except amorphous Si_3N_4 film was deposited on graphite substrate by pyrolysis of SiH_4 and NH_3.
17	T70779	Kijima, K., Stetaka, N., Ishii, M., and Tanaka, H.	1973	2.5–25	293	α-Si_3N_4	Polycrystalline Si_3N_4 film was deposited on Si substrate in 15 min at 1473 K; $\theta \sim 0°$.

TABLE 14-11. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
18	T70731	Mazdiyasni, K.S. and Cooke, C.M.	1973	2.5-50	293	α-Si_3N_4	Si_3N_4 powder prepared by amonolysis of $SiCl_4$ and calcined at 1573 K for 2 hr in vacuum; a 1 mg of the nitride was dispersed in 400 mg of anhydrous spectrographic grade CsI Powder and pressed into disks for infrared studies; $\theta \sim 0°$.
19	T70731	Mazdiyasni, K.S. and Cooke, C.M.	1973	7.4-50	293	α-Si_3N_4	Similar to the above specimen except it was calcined at 1583 K for 2 hr in vacuum.
20	T71498	Buck, J.	1973	2-15	293		Si_3N_4 film was sputtering on KCl substrate by pyrolysis of SiH_4 and NH_3 at 823 K.
21	T71498	Buck, J.	1973	2-15	293		Similar to the above specimen.
22	T71498	Buck, J.	1973	2-15	293		Similar to the above specimen.
23	E9770	Kaiser, W. and Thurmond, C.D.	1959	3.5-15	~293		Si_3N_4 powder was contained in KBr pellet; data were extracted from the smooth figure.
24	E42663	Fränz, I. and Langheinrich, W.	1969	9-14	~293		Amorphous silicon nitride film was applied to the mechanically polished p-type silicon wafer by means of reaction between silane and ammonia at 1000 C, and then was tempered in dry nitrogen for 10 min at 1200 C; data were extracted from the smooth curve; $\theta \sim 0°$.
25	E27985	Lewis, D.W., Esposito, J.N., Dakin, T.W., and Berg, D.	1966	2.5-15	~293	Sample 104-114	Silicon nitride coating was deposited on Mo substrate by pyrolysis of silane and ammonia at reduced pressure; infrared spectra (Nujol) was extracted from the figure; $\theta \sim 0°$.
26	E27985	Lewis, D.W., et al.	1966	2.5-15	~293	Sample 104-113	Similar to the above specimen.
27	E27985	Lewis, D.W., et al.	1966	2.5-4.0	~293	Sample 118-140	Similar to the above specimen except large area of well crystallized α-Si_3N_4 plus some amorphous were formed.
28	E32764	Kuwano, Yukinov'	1968	7.7-15	~293		Silicon nitride film was deposited on 10 Ω-cm N-type silicon wafer by the glow discharge reaction of SiH_4 and NH_3; data were extracted from the smooth curve; $\theta \sim 0°$.
29	E32764	Kuwano, Yukinov'	1968	7.7-15	~293		Silicon nitride film was deposited on 10 Ω-cm N-type silicon wafer by the glow discharge reaction of SiH_4 and N_2; data were extracted from the smooth curve; $\theta \sim 0°$.
30	E32764	Kuwano, Yukinov'	1968	7.7-15	~293		Silicon nitride film was deposited on 10 Ω-cm N-type silicon by the reactive spittering; data were extracted from the smooth curve; $\theta \sim 0°$.
31	E27192	Doo, V.Y., Nichols, D.R., and Silvey, G.A.	1966	2.5-30	~293		Silicon nitride film was deposited on silicon substrate by pyrolytic process by react silane and ammonia in the pressure of excess hydrogen; data were extracted from the smooth curve; $\theta \sim 0°$.
32	E27192	Doo, V.Y., et al.	1966	2.5-30	~293		Similar to the above specimen except it was annealed at 1100 C for 3 hr in N_2 atm.
33	E27192	Doo, V.Y., et al.	1966	2.5-30	~293		Similar to the above specimen.

TABLE 14-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 1	
T = 293.	
0.220	0.000
0.225	0.010
0.230	0.028
0.235	0.064
0.240	0.124
0.250	0.272
0.[illegible]60	0.443
0.270	0.557
0.280	0.622
0.290	0.658
0.300	0.683
0.320	0.700
0.340	0.692
0.370	0.688
0.400	0.682
CURVE 2	
T = 293.	
7.50	0.597
7.94	0.5[illegible]0
8.11	0.494
8.71	0.368
9.16	0.263
9.51	0.203
9.75	0.153
10.07	0.111
10.24	0.086
10.40	0.086
10.55	0.070
11.10	0.052
11.49	0.046
12.02	0.046
12.30	0.063
12.56	0.092
12.94	0.150
13.19	0.212
13.71	0.293
13.96	0.320

λ	τ
CURVE 2 (CONT.)	
14.16	0.352
14.31	0.361
14.64	0.363
14.96	0.385
15.94	0.387
16.57	0.340
17.12	0.388
17.96	0.380
18.37	0.380
18.73	0.362
18.90	0.362
19.27	0.335
19.84	0.304
21.41	0.302
21.72	0.314
22.09	0.320
22.55	0.360
22.79	0.369
23.40	0.337
24.15	0.432
25.00	0.439
CURVE 3	
T = 293.	
2.49	0.675
2.77	0.658
2.85	0.644
2.95	0.590
3.34	0.629
3.90	0.629
4.51	0.603
5.22	0.592
7.57	0.593
7.81	0.575
8.09	0.511
8.32	0.468
8.50	0.453
8.63	0.453
8.86	0.465

λ	τ
CURVE 3 (CONT.)	
9.18	0.464
9.97	0.357
10.21	0.348
10.68	0.292
11.32	0.251
12.05	0.311
12.73	0.362
13.36	0.362
13.36	0.362
14.67	0.375
14.92	0.364
15.32	0.368
15.87	0.355
CURVE 4	
T = 293.	
2.52	0.647
2.79	0.639
2.91	0.575
3.07	0.599
3.35	0.607
3.69	0.576
4.68	0.554
5.87	0.539
7.00	0.504
7.76	0.504
8.24	0.451
8.64	0.421
8.94	0.407
9.28	0.421
10.13	0.356
10.73	0.283
11.30	0.232
11.90	0.295
12.43	0.369
12.30	0.407
13.16	0.418
13.63	0.422
13.97	0.458

λ	τ
CURVE 4 (CONT.)	
14.70	0.475
15.93	0.475
CURVE 5	
T = 293.	
2.33	0.682
2.66	0.673
2.79	0.656
2.95	0.629
3.30	0.647
3.78	0.647
4.63	0.631
5.43	0.623
6.68	0.623
7.24	0.614
7.76	0.599
8.23	0.555
8.68	0.537
8.98	0.511
9.30	0.533
9.69	0.506
9.95	0.505
10.50	0.453
11.02	0.404
11.43	0.416
11.85	0.478
12.46	0.515
13.00	0.541
13.58	0.541
14.12	0.571
14.72	0.574
15.86	0.581
CURVE 6	
T = 293.	
7.23	0.495
7.64	0.492
7.84	0.482

λ	τ
CURVE 6 (CONT.)	
8.13	0.468
8.47	0.448
8.76	0.423
9.02	0.388
9.35	0.374
9.55	0.350
9.86	0.313
10.17	0.273
10.52	0.232
10.96	0.220
11.31	0.209
11.70	0.209
12.00	0.225
12.36	0.252
12.66	0.301
12.89	0.336
13.12	0.381
13.64	0.423
14.03	0.446
14.51	0.464
15.38	0.469
CURVE 7	
T = 293.	
3.17	0.834
3.59	0.919
4.02	0.985
4.47	0.010
4.82	0.010
5.88	0.010
6.31	0.988
6.65	0.974
6.80	0.959
7.00	0.941
7.30	0.907
7.52	0.878
7.74	0.843
8.06	0.793
8.22	0.748

λ	τ
CURVE 7 (CONT.)	
8.40	0.712
8.56	0.670
9.00	0.565
9.26	0.514
9.55	0.461
9.80	0.403
10.06	0.346
10.28	0.307
10.62	0.267
10.73	0.253
11.02	0.223
11.21	0.204
11.44	0.196
12.19	0.196
12.51	0.230
12.77	0.255
12.99	0.303
13.22	0.345
13.50	0.402
13.96	0.480
14.18	0.528
14.35	0.551
14.55	0.568
14.70	0.579
15.00	0.585
CURVE 8	
T = 293.	
1.759	0.000
1.785	0.030
1.846	0.365
1.871	0.550
1.895	0.693
1.931	0.809
1.959	0.877
1.968	0.893
1.976	0.906
2.001	0.919
2.017	0.925

TABLE 14-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 8 (CONT.)	
2.035	0.930
2.062	0.930
2.095	0.929
2.153	0.916
2.216	0.902
2.267	0.888
2.323	0.879
2.371	0.866
2.428	0.856
2.504	0.841
CURVE 9	
T = 293.	
1.003	0.000
1.048	0.560
1.054	0.721
1.063	0.796
1.074	0.847
1.087	0.874
1.097	0.898
1.113	0.919
1.130	0.934
1.144	0.943
1.160	0.951
1.184	0.951
1.220	0.934
1.266	0.912
1.324	0.885
1.393	0.860
1.494	0.822
1.566	0.794
1.694	0.754
1.839	0.710
1.980	0.674
2.142	0.631

λ	τ
CURVE 10	
T = 293.	
0.912	0.000
0.921	0.312
0.933	0.525
1.112	0.689
1.208	0.771
1.299	0.850
1.339	0.874
1.379	0.901
1.413	0.920
1.453	0.941
1.502	0.959
1.550	0.970
1.606	0.978
1.700	0.978
1.762	0.972
1.819	0.961
1.899	0.946
1.960	0.930
2.036	0.912
2.150	0.882
2.284	0.843
CURVE 11	
T = 293.	
0.9616	0.0000
1.0000	0.0590
1.0839	0.4460
1.1588	0.7800
1.1885	0.8540
1.2388	0.9280
1.2388	0.9560
1.2618	0.9760
1.2972	1.0000
1.3428	0.9730
1.3964	0.9260
1.4380	0.8460
1.4962	0.7570
1.5740	0.6630

λ	τ
CURVE 11 (CONT.)	
1.6596	0.5940
1.7258	0.5660
1.7824	0.5400
1.8664	0.5360
1.9320	0.5360
2.0277	0.5450
2.1038	0.5620
2.2088	0.5860
2.2900	0.6110
2.3933	0.6450
2.5704	0.7230
2.7925	0.8850
2.9648	0.8600
3.0903	0.7000
3.2137	0.9290
3.3113	0.9490
3.4190	0.9680
3.5075	0.9800
3.6475	0.9930
3.8107	0.9930
4.0551	0.9810
4.2755	0.9620
4.5186	0.9370
4.[illegible]973	0.8950
5.2481	0.8230
6.0395	0.7220
6.3680	0.6750
6.9343	0.6310
7.4817	0.5920
7.9799	0.5600
8.2985	0.4820
8.6099	0.4070
8.9536	0.2850
9.1411	0.2600
9.7051	0.2410
9.0620	0.2050
10.0925	0.1720
10.2094	0.1480
10.4713	0.1280
11.0154	0.1100

λ	τ
CURVE 11 (CONT.)	
11.6145	0.0970
12.2462	0.0970
12.8529	0.1090
13.5519	0.1340
13.8995	0.1670
15.4170	0.2630
16.0694	0.2730
17.0216	0.3370
18.0717	0.4040
20.3704	0.4070
CURVE 12	
T = 293.	
7.05	0.588
7.09	0.581
7.14	0.574
7.23	0.569
7.35	0.566
7.40	0.572
7.46	0.561
7.63	0.563
7.76	0.563
7.80	0.568
7.87	0.563
7.99	0.560
8.08	0.567
8.20	0.567
8.30	0.564
8.40	0.560
8.48	0.562
8.58	0.562
8.61	0.565
8.61	0.562
8.73	0.559
8.84	0.558
8.87	0.561
8.87	0.556
9.04	0.556
9.23	0.555

λ	τ
CURVE 12 (CONT.)	
9.29	0.560
9.35	0.556
9.51	0.553
9.80	0.553
10.02	0.549
10.13	0.545
10.24	0.545
10.24	0.540
10.37	0.533
10.53	0.511
10.73	0.494
10.73	0.475
10.83	0.467
10.98	0.477
11.09	0.464
11.22	0.459
11.31	0.445
11.38	0.469
11.56	0.479
11.67	0.469
11.67	0.445
11.81	0.428
11.95	0.483
12.12	0.507
12.27	0.523
12.32	0.539
12.55	0.544
13.00	0.547
13.32	0.540
13.42	0.542
13.42	0.540
13.72	0.535
14.25	0.538
14.39	0.520
14.64	0.513
14.71	0.495
14.93	0.492
15.08	0.495
15.15	0.485

λ	τ
CURVE 13	
T = 293.	
7.05	0.426
7.11	0.443
7.11	0.453
7.14	0.458
7.18	0.472
7.23	0.475
7.28	0.478
7.41	0.478
7.41	0.487
7.50	0.485
7.54	0.487
7.63	0.488
7.70	0.484
7.75	0.488
7.82	0.485
7.89	0.480
7.89	0.488
8.01	0.489
8.12	0.489
8.20	0.486
8.27	0.490
8.35	0.486
8.53	0.484
8.81	0.480
8.94	0.483
9.17	0.481
9.45	0.481
9.73	0.476
10.00	0.471
10.22	0.466
10.44	0.458
10.63	0.449
10.74	0.430
10.82	0.411
11.05	0.403
11.24	0.368
11.39	0.385
11.57	0.398
11.68	0.386

TABLE 14-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 13 (CONT.)	
11.74	0.366
11.92	0.351
12.08	0.408
12.21	0.437
12.36	0.464
12.53	0.474
12.71	0.480
13.02	0.483
13.30	0.478
13.51	0.471
13.61	0.464
14.08	0.460
14.16	0.450
14.33	0.446
14.41	0.434
14.66	0.424
CURVE 14	
T = 293.	
7.13	0.398
7.16	0.407
7.19	0.412
7.21	0.410
7.24	0.413
7.27	0.409
7.32	0.416
7.38	0.409
7.42	0.420
7.46	0.412
7.56	0.413
7.56	0.419
7.63	0.418
7.67	0.421
7.72	0.417
7.76	0.426
7.81	0.418
7.83	0.424
7.89	0.420
7.99	0.417

λ	τ
CURVE 14 (CONT.)	
8.08	0.420
8.19	0.418
8.28	0.421
8.28	0.419
8.49	0.416
8.58	0.408
8.63	0.414
8.66	0.409
8.75	0.406
8.80	0.411
8.89	0.395
8.94	0.404
8.98	0.402
9.35	0.394
9.43	0.395
9.47	0.389
9.62	0.389
9.81	0.382
10.00	0.368
10.28	0.347
10.40	0.328
10.60	0.313
10.67	0.286
10.82	0.281
11.01	0.231
11.11	0.232
11.30	0.216
11.43	0.198
11.56	0.192
11.64	0.220
11.70	0.211
11.78	0.216
11.83	0.180
11.99	0.173
12.14	0.185
12.20	0.215
12.33	0.221
12.33	0.243
12.41	0.261
12.50	0.291

λ	τ
CURVE 14 (CONT.)	
12.74	0.322
12.90	0.350
13.00	0.368
13.09	0.364
13.25	0.381
13.46	0.383
13.59	0.393
13.83	0.387
13.97	0.390
14.10	0.383
14.18	0.394
14.18	0.387
14.45	0.390
14.58	0.372
14.71	0.360
14.79	0.356
14.90	0.342
15.06	0.338
15.22	0.340
15.38	0.337
CURVE 15	
T = 293.	
2.50	0.354
2.50	0.354
2.54	0.364
2.65	0.367
2.68	0.379
2.76	0.387
2.82	0.401
3.09	0.401
3.15	0.376
3.20	0.381
3.26	0.370
3.30	0.326
3.33	0.245
3.37	0.000
3.52	0.000
3.57	0.224

λ	τ
CURVE 15 (CONT.)	
3.60	0.354
3.62	0.377
3.64	0.390
3.67	0.363
3.70	0.385
3.75	0.385
3.85	0.440
3.92	0.474
4.01	0.511
4.07	0.525
4.19	0.525
4.24	0.548
4.37	0.548
4.69	0.599
5.00	0.642
5.28	0.667
5.44	0.682
5.54	0.693
5.70	0.706
5.74	0.695
5.79	0.710
6.15	0.724
6.44	0.724
6.55	0.708
6.63	0.681
6.69	0.624
6.80	0.034
6.85	0.015
6.93	0.058
7.01	0.498
7.04	0.547
7.12	0.581
7.17	0.540
7.28	0.073
7.30	0.205
7.34	0.215
7.36	0.370
7.46	0.410
7.55	0.470
7.68	0.435

λ	τ
CURVE 15 (CONT.)	
7.79	0.441
8.01	0.414
8.44	0.325
8.68	0.270
8.83	0.270
9.29	0.227
9.51	0.232
9.79	0.220
10.15	0.215
10.30	0.200
10.72	0.200
11.10	0.215
11.42	0.230
11.71	0.230
12.72	0.290
13.30	0.323
13.87	0.284
14.04	0.368
14.20	0.426
14.95	0.480
15.27	0.480
16.26	0.529
16.26	0.548
16.56	0.541
17.48	0.579
18.59	0.579
19.01	0.548
19.96	0.455
21.55	0.434
23.36	0.487
26.18	0.536
27.03	0.529
27.83	0.563
28.90	0.601
31.95	0.640
34.36	0.640
35.71	0.618
40.00	0.544

λ	τ
CURVE 16	
T = 293.	
2.50	0.218
2.61	0.229
2.70	0.244
2.95	0.280
3.05	0.280
3.11	0.293
3.16	0.297
3.22	0.307
3.28	0.308
3.31	0.289
3.34	0.265
3.37	0.151
3.38	0.028
3.44	0.020
3.48	0.052
3.52	0.031
3.54	0.204
3.55	0.306
3.58	0.350
3.60	0.376
3.62	0.394
3.65	0.394
3.69	0.387
3.72	0.402
3.76	0.402
3.80	0.417
4.06	0.473
4.36	0.513
4.63	0.542
4.80	0.564
5.00	0.583
5.14	0.594
5.41	0.619
5.73	0.645
6.08	0.670
6.22	0.679
6.32	0.679
6.38	0.687
6.59	0.687

TABLE 14-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 16 (CONT.)		CURVE 16 (CONT.)		CURVE 17 (CONT.)		CURVE 17 (CONT.)		CURVE 18 (CONT.)		CURVE 18 (CONT.)	
6.65	0.676	13.30	0.377	3.11	0.568	19.96	0.651	4.28	0.398	9.25	0.256
6.70	0.660	13.64	0.420	3.28	0.567	20.75	0.642	4.43	0.404	9.37	0.207
6.73	0.630	13.95	0.433	3.36	0.574	21.74	0.638	4.54	0.413	9.61	0.153
6.78	0.543	14.06	0.484	3.42	0.566	23.70	0.603	4.62	0.413	9.71	0.156
6.83	0.246	14.35	0.524	3.51	0.577	25.00	0.613	4.65	0.421	9.82	0.150
6.36	0.223	14.66	0.533	3.81	0.576			4.83	0.432	9.98	0.125
6.90	0.250	14.66	0.546	3.91	0.585	CURVE 18		4.94	0.432	10.27	0.128
6.93	0.364	15.90	0.590	4.12	0.573	T = 293.		4.97	0.437	10.52	0.137
6.99	0.591	17.06	0.621	4.33	0.592			5.00	0.441	10.62	0.132
7.03	0.677	18.12	0.621	4.72	0.592	2.50	0.264	5.01	0.458	10.71	0.118
7.12	0.700	18.73	0.606	4.85	0.587	2.59	0.266	5.13	0.458	10.76	0.154
7.16	0.633	19.38	0.579	5.10	0.587	2.60	0.270	5.22	0.467	10.83	0.165
7.19	0.669	20.12	0.545	5.19	0.600	2.67	0.270	5.34	0.469	10.86	0.199
7.24	0.479	20.53	0.545	5.59	0.600	2.70	0.279	5.37	0.473	10.89	0.206
7.28	0.359	21.23	0.561	5.75	0.600	2.89	0.279	5.44	0.473	11.01	0.150
7.30	0.518	22.37	0.686	5.93	0.612	2.91	0.286	5.46	0.481	11.05	0.221
7.34	0.532	23.58	0.647	6.62	0.618	2.96	0.286	5.55	0.481	11.11	0.161
7.36	0.616	24.75	0.681	7.13	0.622	2.98	0.300	5.61	0.484	11.17	0.144
7.51	0.666	25.45	0.695	7.35	0.633	3.06	0.302	5.64	0.489	11.26	0.168
7.57	0.675	26.04	0.695	7.50	0.632	3.08	0.309	5.76	0.489	11.33	0.352
7.68	0.660	26.67	0.679	7.69	0.629	3.12	0.309	5.78	0.497	11.36	0.234
7.79	0.665	26.95	0.688	7.84	0.637	3.16	0.312	5.83	0.491	11.42	0.212
7.89	0.644	26.95	0.729	8.14	0.635	3.19	0.318	5.93	0.501	11.52	0.270
8.08	0.593	28.25	0.751	8.67	0.640	3.23	0.318	6.24	0.504	11.70	0.155
8.32	0.526	29.33	0.757	8.93	0.629	3.28	0.325	6.34	0.515	11.79	0.357
8.45	0.505	31.85	0.757	9.64	0.651	3.35	0.331	6.52	0.517	11.85	0.433
8.78	0.402	33.56	0.745	9.95	0.640	3.41	0.331	6.76	0.523	11.88	0.492
9.07	0.291	35.09	0.717	10.22	0.630	3.44	0.337	6.86	0.528	12.00	0.550
9.31	0.232	36.36	0.693	10.56	0.629	3.47	0.337	7.17	0.528	12.11	0.586
9.57	0.184	38.31	0.597	10.95	0.609	3.49	0.344	7.41	0.540	12.41	0.622
9.90	0.160	40.00	0.590	11.52	0.563	3.54	0.344	7.69	0.545	12.76	0.650
10.35	0.141			12.09	0.512	3.56	0.351	8.05	0.545	13.35	0.662
10.85	0.141	CURVE 17		12.77	0.497	3.65	0.351	8.34	0.542	14.33	0.674
11.27	0.151	T = 293.		13.77	0.573	3.71	0.357	8.47	0.532	14.43	0.635
11.67	0.163			15.13	0.657	3.84	0.370	8.73	0.517	14.47	0.512
11.96	0.171	2.50	0.554	15.67	0.654	3.89	0.369	8.82	0.501	14.51	0.603
12.25	0.199	2.66	0.556	16.08	0.661	3.99	0.381	8.91	0.479	14.60	0.634
12.50	0.230	2.69	0.550	17.36	0.661	4.05	0.381	8.97	0.453	14.66	0.610
12.77	0.270	2.73	0.559	18.02	0.673	4.07	0.386	9.07	0.363	14.77	0.672
12.99	0.303	2.88	0.563	18.55	0.662	4.19	0.390	9.16	0.306	14.93	0.676

TABLE 14-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 18(CONT.)		CURVE 18(CONT.)		CURVE 19(CONT.)		CURVE 19(CONT.)		CURVE 19(CONT.)		CURVE 19(CONT.)	
15.24	0.696	27.70	0.605	7.96	0.516	11.93	0.240	21.51	0.687	40.82	0.727
15.80	0.699	27.93	0.718	8.08	0.512	12.02	0.322	21.83	0.433	41.67	0.734
15.80	0.730	28.33	0.734	8.22	0.502	12.12	0.400	21.98	0.701	42.92	0.727
15.90	0.726	30.21	0.741	8.32	0.495	12.25	0.455	22.32	0.719	43.67	0.688
15.26	0.726	30.77	0.732	8.40	0.487	12.47	0.525	22.37	0.693	44.44	0.717
16.50	0.598	31.75	0.735	8.43	0.490	12.67	0.534	22.62	0.685	45.45	0.724
16.56	0.710	32.57	0.656	8.45	0.478	12.94	0.615	23.15	0.695	45.45	0.724
16.69	0.731	33.00	0.721	8.54	0.467	13.18	0.636	23.70	0.708	48.08	0.724
17.61	0.735	33.44	0.743	8.64	0.452	13.46	0.652	24.10	0.686	50.00	0.713
17.95	0.745	33.78	0.790	8.73	0.426	13.70	0.663	24.51	0.309		
18.80	0.750	34.13	0.754	8.82	0.401	14.10	0.672	24.94	0.582	CURVE 20	
19.16	0.742	34.36	0.792	8.89	0.362	14.43	0.663	25.19	0.688	T = 293.	
19.38	0.467	35.09	0.751	8.98	0.319	14.53	0.602	25.64	0.710		
19.53	0.601	35.46	0.762	9.07	0.244	14.64	0.443	26.04	0.698	2.06	0.725
19.76	0.385	35.59	0.737	9.17	0.193	14.73	0.590	26.46	0.687	2.12	0.737
20.00	0.346	35.59	0.767	9.24	0.157	14.77	0.567	27.03	0.302	2.39	0.755
20.24	0.698	36.50	0.780	9.30	0.128	14.86	0.629	27.17	0.650	2.67	0.790
20.45	0.730	37.04	0.751	9.47	0.108	14.95	0.651	27.47	0.688	2.81	0.790
20.62	0.750	37.31	0.766	9.49	0.099	15.20	0.678	27.62	0.670	2.92	0.769
21.19	0.750	38.31	0.777	9.69	0.092	15.58	0.684	27.86	0.699	2.99	0.781
21.41	0.493	38.76	0.813	9.76	0.097	15.90	0.689	28.33	0.489	3.15	0.804
21.55	0.722	39.06	0.737	9.85	0.090	16.29	0.689	28.57	0.703	3.25	0.814
21.74	0.754	39.37	0.813	9.95	0.080	16.56	0.678	29.50	0.712	3.55	0.816
22.22	0.754	39.37	0.784	10.09	0.068	16.72	0.486	31.06	0.712	3.66	0.825
22.47	0.749	40.32	0.767	10.58	0.068	16.81	0.633	31.65	0.720	4.09	0.826
22.99	0.754	42.37	0.779	10.78	0.058	16.86	0.675	31.95	0.711	4.18	0.838
23.47	0.748	43.10	0.806	10.89	0.081	17.01	0.691	32.79	0.711	4.50	0.819
23.70	0.732	44.05	0.781	10.98	0.107	17.42	0.676	33.11	0.586	4.74	0.829
24.16	0.457	47.17	0.787	11.06	0.077	18.05	0.700	33.11	0.662	4.93	0.846
24.27	0.628	50.00	0.784	11.14	0.110	18.76	0.704	33.78	0.522	5.32	0.855
24.69	0.636			11.19	0.082	19.12	0.694	34.13	0.682	5.75	0.867
24.69	0.724	CURVE 19		11.26	0.071	19.38	0.677	34.48	0.706	5.85	0.861
25.13	0.744	T = 293.		11.33	0.082	19.69	0.332	35.34	0.706	5.92	0.874
25.64	0.739			11.39	0.202	19.88	0.467	35.71	0.642	6.05	0.864
25.91	0.703	7.44	0.503	11.44	0.171	20.04	0.259	36.10	0.699	6.24	0.878
26.39	0.468	7.47	0.507	11.47	0.113	20.24	0.211	36.50	0.711	6.36	0.873
26.53	0.703	7.50	0.518	11.60	0.137	20.45	0.252	37.31	0.711	6.54	0.882
26.74	0.725	7.55	0.510	11.67	0.109	20.66	0.603	37.45	0.744	6.79	0.884
26.95	0.714	7.69	0.512	11.74	0.072	20.88	0.664	38.31	0.737	6.94	0.895
27.25	0.727	7.74	0.516	11.81	0.097	21.32	0.693	39.53	0.742	7.04	0.893

TABLE 14-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 20 (CONT.)	
7.24	0.893
7.39	0.899
7.59	0.899
7.79	0.890
8.21	0.828
8.31	0.743
9.22	0.694
9.85	0.586
10.19	0.548
10.47	0.523
10.73	0.507
11.34	0.507
11.44	0.522
11.94	0.547
12.21	0.593
12.51	0.628
12.81	0.680
13.28	0.724
14.01	0.790
14.26	0.816
14.69	0.829
14.85	0.847
14.93	0.832
15.04	0.849
15.38	0.854
15.44	0.848
15.55	0.843
CURVE 21	
T = 293.	
1.92	0.846
3.11	0.852
2.19	0.861
2.25	0.881
2.46	0.881
2.54	0.870
2.69	0.864
2.73	0.845
2.94	0.810

λ	τ
CURVE 21 (CONT.)	
3.18	0.792
3.31	0.799
3.42	0.739
3.54	0.788
3.94	0.770
4.20	0.761
4.45	0.761
4.69	0.768
4.76	0.780
5.01	0.786
5.62	0.815
6.05	0.838
6.22	0.842
6.39	0.860
6.72	0.870
7.14	0.881
7.36	0.888
7.58	0.888
7.75	0.874
7.84	0.874
8.16	0.815
8.29	0.774
8.56	0.743
8.56	0.[illegible]26
8.65	0.716
8.83	0.669
8.93	0.635
9.14	0.583
9.44	0.539
9.74	0.501
10.13	0.469
10.79	0.422
11.06	0.413
11.28	0.413
11.69	0.396
12.27	0.405
12.63	0.424
13.08	0.462
13.64	0.517
14.27	0.575

λ	τ
CURVE 21 (CONT.)	
14.79	0.612
14.90	0.629
15.02	0.622
15.17	0.629
CURVE 22	
T = 293.	
1.98	0.835
2.13	0.825
2.13	0.809
2.29	0.804
2.49	0.767
2.78	0.727
2.78	0.711
3.00	0.686
3.14	0.696
3.27	0.702
3.57	0.702
3.95	0.709
4.23	0.723
4.37	0.716
4.60	0.721
4.69	0.739
5.12	0.760
5.66	0.793
6.34	0.820
6.71	0.859
7.13	0.869
7.21	0.864
7.32	0.877
7.69	0.875
7.99	0.835
7.99	0.821
8.13	0.801
8.13	0.782
8.29	0.760
8.29	0.736
8.60	0.701
8.76	0.630

λ	τ
CURVE 22 (CONT.)	
8.91	0.576
9.19	0.495
9.67	0.409
10.03	0.371
10.33	0.317
10.54	0.287
10.99	0.260
11.48	0.238
11.85	0.237
12.06	0.246
12.43	0.257
12.70	0.290
13.27	0.375
13.85	0.453
14.14	0.499
14.51	0.544
14.90	0.583
14.98	0.572
15.06	0.584
CURVE 23	
T = 293.	
3.85	0.896
3.85	0.896
5.88	0.896
6.17	0.890
6.88	0.886
7.12	0.879
7.44	0.868
7.83	0.848
8.09	0.806
8.38	0.767
8.67	0.713
8.81	0.664
9.13	0.501
9.35	0.423
9.57	0.379
9.73	0.498
9.98	0.377

λ	τ
CURVE 23 (CONT.)	
10.09	0.317
10.52	0.269
10.84	0.304
11.25	0.523
11.43	0.594
11.64	0.636
11.86	0.684
12.19	0.721
12.53	0.756
13.06	0.789
13.61	0.822
14.42	0.854
CURVE 24	
T = 293.	
8.98	0.619
9.22	0.593
9.49	0.550
9.72	0.508
9.95	0.466
10.21	0.410
10.42	0.373
10.64	0.341
10.92	0.317
11.20	0.302
11.63	0.302
11.90	0.310
12.12	0.333
12.36	0.357
12.56	0.386
12.79	0.424
13.00	0.468
13.28	0.522
13.59	0.575
13.79	0.604
13.97	0.621
14.16	0.636
14.45	0.650
14.77	0.659

λ	τ
CURVE 24 (CONT.)	
15.22	0.664
15.72	0.664
CURVE 25	
T = 293.	
2.50	0.393
2.57	0.414
2.67	0.450
2.75	0.445
2.77	0.465
2.81	0.452
2.86	0.475
2.98	0.475
3.04	0.487
3.10	0.487
3.20	0.503
3.20	0.518
3.27	0.531
3.37	0.566
3.44	0.550
3.49	0.453
3.53	0.073
3.57	0.039
3.60	0.148
3.64	0.115
3.67	0.501
3.70	0.630
3.75	0.673
3.81	0.669
3.94	0.705
4.05	0.748
4.29	0.785
4.34	0.829
4.38	0.802
4.45	0.796
4.49	0.820
4.70	0.851
4.91	0.870
5.11	0.896

TABLE 14-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 25(CONT.)		CURVE 25(CONT.)		CURVE 26(CONT.)		CURVE 26(CONT.)		CURVE 27(CONT.)		CURVE 27(CONT.)	
5.41	0.919	7.47	0.833	3.33	0.737	7.93	0.891	2.99	0.839	4.31	0.769
5.80	0.934	7.58	0.851	3.44	0.726	8.10	0.863	3.05	0.876	4.34	0.765
5.89	0.920	7.64	0.866	3.49	0.608	8.16	0.838	3.12	0.920	4.62	0.809
5.92	0.948	7.78	0.834	3.51	0.298	8.23	0.828	3.16	0.927	4.72	0.826
5.95	0.918	7.90	0.819	3.56	0.251	8.37	0.754	3.19	0.951	4.75	0.841
6.03	0.936	8.02	0.759	3.61	0.401	8.50	0.686	3.20	0.976	4.81	0.841
6.06	0.914	8.21	0.560	3.63	0.355	8.71	0.628	3.21	0.954	4.96	0.861
6.12	0.904	8.48	0.249	3.68	0.703	9.00	0.583	3.22	0.963	5.03	0.871
6.15	0.927	8.59	0.190	3.71	0.757	9.15	0.552	3.25	0.969	5.14	0.873
6.19	0.899	8.72	0.164	3.76	0.794	9.53	0.512	3.29	0.961	5.16	0.883
6.21	0.921	8.88	0.151	3.82	0.789	9.81	0.488	3.31	0.938	5.27	0.888
6.24	0.901	9.11	0.129	3.97	0.805	9.87	0.474	3.32	0.896	5.41	0.907
6.30	0.919	9.50	0.108	4.08	0.833	10.09	0.468	3.35	0.704	5.73	0.924
6.42	0.930	9.89	0.091	4.34	0.855	10.33	0.453	3.38	0.201	5.80	0.924
6.46	0.939	10.10	0.091	4.43	0.850	10.71	0.438	3.39	0.153	5.90	0.935
6.48	0.932	10.52	0.076	4.46	0.861	11.15	0.438	3.40	0.148	5.97	0.936
6.50	0.949	11.33	0.076	4.87	0.889	11.64	0.458	3.43	0.101	6.03	0.931
6.53	0.921	11.95	0.084	5.34	0.917	12.18	0.472	3.45	0.152	6.18	0.931
6.57	0.948	12.34	0.092	6.01	0.926	12.48	0.499	3.47	0.299	6.45	0.948
6.61	0.923	12.74	0.129	6.35	0.926	13.01	0.558	3.48	0.319	6.60	0.948
6.65	0.941	12.89	0.129	6.69	0.930	13.36	0.590	3.49	0.256	6.69	0.932
6.69	0.925	13.36	0.157	6.82	0.919	13.48	0.600	3.51	0.221	6.73	0.902
6.72	0.940	13.59	0.162	6.89	0.849	13.63	0.600	3.54	0.897	6.77	0.813
6.74	0.901	13.74	0.173	6.92	0.671	13.77	0.620	3.55	1.000	6.84	0.383
9.76	0.922	13.99	0.192	6.96	0.634	13.88	0.621	3.58	1.000	6.86	0.370
6.81	0.904	14.16	0.228	6.99	0.656	14.24	0.684	3.58	0.551	6.89	0.389
6.85	0.845	14.42	0.248	7.03	0.780	14.41	0.697	3.60	0.580	6.92	0.503
6.89	0.740	14.62	0.261	7.11	0.897	14.71	0.721	3.63	0.591	7.02	0.876
6.92	0.498	14.84	0.262	7.20	0.926	14.83	0.736	3.68	0.584	7.06	0.905
6.94	0.416	15.00	0.268	7.27	0.919	15.00	0.754	3.71	0.600	7.09	0.916
6.99	0.449			7.33	0.803			3.76	0.600	7.13	0.926
7.09	0.600	CURVE 26		7.37	0.740	CURVE 27		3.87	0.646	7.16	0.918
7.11	0.835	T = 293.		7.39	0.804	T = 293.		3.97	0.673	7.19	0.890
7.13	0.863			7.43	0.827			4.00	0.695	7.28	0.526
7.16	0.676	2.50	0.642	7.46	0.874	2.50	0.649	4.02	0.695	7.32	0.714
7.21	0.905	2.53	0.703	7.51	0.885	2.55	0.672	4.04	0.711	7.35	0.721
7.26	0.890	2.54	0.664	7.59	0.885	2.72	0.767	4.06	0.696	7.37	0.802
7.36	0.598	2.86	0.698	7.63	0.900	2.82	0.792	4.10	0.717	7.41	0.833
7.39	0.731	3.25	0.729	7.67	0.901	2.89	0.806	4.21	0.733	7.57	0.884
7.43	0.747	3.31	0.724	7.76	0.891	2.94	0.821	4.26	0.759	7.70	0.870

TABLE 14-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 27 (CONT.)	
7.78	0.874
7.84	0.874
7.99	0.862
8.19	0.822
8.40	0.753
8.55	0.686
8.79	0.538
8.84	0.520
9.09	0.340
9.23	0.234
9.29	0.188
9.43	0.164
9.63	0.157
9.80	0.135
9.91	0.135
10.24	0.098
10.56	0.084
10.70	0.082
10.78	0.075
11.03	0.101
11.15	0.095
11.24	0.099
11.35	0.091
11.48	0.116
11.82	0.095
12.38	0.133
12.82	0.165
13.18	0.189
13.62	0.202
14.37	0.202
14.56	0.197
14.73	0.165
14.95	0.165
15.15	0.168
15.65	0.152
16.00	0.171
16.00	0.134
16.00	0.152
16.45	0.131
16.69	0.134

λ	τ
CURVE 27 (CONT.)	
16.84	0.124
17.79	0.297
18.69	0.502
19.01	0.550
19.34	0.564
19.57	0.536
19.80	0.358
20.08	0.351
20.62	0.152
21.14	0.286
21.55	0.230
21.98	0.141
22.57	0.199
24.27	0.445
24.63	0.316
25.13	0.381
25.58	0.573
25.97	0.614
26.46	0.589
27.03	0.305
28.17	0.727
28.65	0.634
28.99	0.755
29.76	0.834
30.58	0.860
32.68	0.892
34.13	0.806
34.72	0.860
35.59	0.881
36.50	0.881
36.90	0.906
39.06	0.927
39.06	1.000
CURVE 28	
T = 293.	
7.72	0.677
7.96	0.647
8.20	0.613

λ	τ
CURVE 28 (CONT.)	
8.42	0.581
8.76	0.581
9.02	0.559
9.38	0.516
9.78	0.474
10.20	0.433
10.70	0.397
11.16	0.367
11.53	0.367
11.78	0.388
12.11	0.426
12.42	0.473
12.66	0.521
12.99	0.580
13.40	0.654
13.89	0.705
14.25	0.735
14.68	0.765
14.95	0.776
15.43	0.791
CURVE 29	
T = 293.	
7.93	0.680
8.14	0.671
8.34	0.662
8.61	0.635
8.85	0.609
9.10	0.576
9.44	0.537
9.79	0.487
10.11	0.440
10.37	0.409
10.63	0.371
10.98	0.327
11.39	0.277
11.61	0.242
11.85	0.224
12.09	0.224

λ	τ
CURVE 29 (CONT.)	
12.22	0.236
12.44	0.273
12.61	0.319
12.80	0.380
13.07	0.443
13.35	0.512
13.59	0.554
13.83	0.594
14.08	0.624
14.41	0.661
14.66	0.682
14.99	0.705
15.41	0.720
15.80	0.720
16.10	0.706
16.37	0.665
16.56	0.630
16.84	0.607
17.09	0.619
17.36	0.637
CURVE 30	
T = 293.	
7.75	0.689
7.95	0.667
8.08	0.650
8.22	0.628
8.45	0.585
8.76	0.532
8.90	0.498
9.06	0.475
9.23	0.457
9.51	0.447
9.77	0.431
10.07	0.386
10.40	0.338
10.82	0.288
11.25	0.246
11.64	0.214

λ	τ
CURVE 30 (CONT.)	
11.98	0.190
12.17	0.190
12.45	0.220
12.69	0.273
13.05	0.348
13.35	0.421
13.76	0.518
14.01	0.558
14.37	0.591
CURVE 31	
T = 293.	
2.50	0.592
2.62	0.638
2.68	0.652
2.72	0.670
2.79	0.700
2.85	0.700
2.92	0.680
33.26	0.937
3.11	0.609
3.24	0.578
3.40	0.556
3.57	0.556
3.70	0.579
3.84	0.607
3.98	0.633
4.19	0.677
4.32	0.677
4.49	0.701
4.65	0.702
4.91	0.664
5.00	0.650
5.13	0.631
5.26	0.609
5.44	0.581
5.72	0.554
5.85	0.548
5.96	0.535

λ	τ
CURVE 31 (CONT.)	
6.34	0.541
6.69	0.542
6.80	0.555
7.03	0.555
7.42	0.583
7.70	0.583
7.82	0.562
7.97	0.533
8.12	0.476
8.33	0.379
8.70	0.272
8.94	0.188
9.27	0.111
9.66	0.072
10.24	0.033
11.20	0.018
12.42	0.018
12.76	0.044
13.30	0.114
13.46	0.167
13.85	0.226
14.27	0.258
14.45	0.286
15.75	0.321
16.16	0.310
16.58	0.301
16.78	0.333
17.12	0.346
17.86	0.346
18.28	0.311
19.34	0.263
20.49	0.241
21.88	0.285
23.70	0.338
25.84	0.374
27.40	0.399
29.85	0.425

TABLE 14-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON NITRIDE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 32 T = 293.	
2.50	0.453
2.63	0.479
2.71	0.507
2.79	0.533
2.86	0.533
2.91	0.514
2.95	0.489
3.04	0.450
3.17	0.442
3.33	0.429
3.81	0.429
3.65	0.451
3.77	0.484
3.91	0.509
4.03	0.527
4.20	0.553
4.54	0.573
4.69	0.572
4.81	0.554
5.00	0.531
5.15	0.509
5.33	0.488
5.50	0.476
5.62	0.467
5.71	0.448
6.61	0.447
6.97	0.463
7.28	0.489
7.50	0.501
7.44	0.504
7.76	0.502
7.97	0.478
8.12	0.435
8.25	0.372
8.50	0.285
8.68	0.230
9.04	0.138
9.31	0.086
9.68	0.059

λ	τ
CURVE 32 (CONT.)	
10.18	0.030
11.22	0.008
12.35	0.009
12.90	0.035
13.32	0.110
13.91	0.194
14.62	0.266
14.99	0.279
15.62	0.297
16.05	0.309
16.67	0.296
17.36	0.333
18.42	0.321
18.55	0.309
20.08	0.230
20.70	0.223
21.83	0.258
23.98	0.323
25.84	0.369
27.62	0.399
32.79	0.417
CURVE 33 T = 293.	
2.50	0.453
2.58	0.463
2.66	0.488
2.77	0.507
2.86	0.507
2.93	0.480
3.00	0.452
3.16	0.438
3.32	0.427
3.49	0.422
3.64	0.438
3.77	0.453
3.87	0.481
4.04	0.518
4.45	0.558

λ	τ
CURVE 33 (CONT.)	
4.61	0.558
4.79	0.540
4.96	0.509
5.13	0.506
5.29	0.480
5.53	0.459
5.81	0.436
6.31	0.435
6.63	0.446
6.97	0.463
7.28	0.489
7.50	0.501
7.65	0.502
7.89	0.480
8.03	0.454
8.25	0.372
8.50	0.285
8.68	0.230
9.04	0.138
9.31	0.086
9.68	0.059
10.18	0.030
11.22	0.008
12.35	0.009
12.90	0.035
13.32	0.110
13.91	0.194
14.62	0.266
15.95	0.296
16.58	0.287
17.33	0.324
18.55	0.309
20.70	0.214
23.20	0.293
25.91	0.363
29.85	0.383

4.15. Acrylic Resins

The four major categories of acrylic resins include polymethacrylate, polyacrylate, poly(methyl methacrylate), and copolymer of acrylonitrile. The list of esters range from methyl to lauryl, C_1-C_{15}. Because of the many combinations possible, there are at least 40 varieties of acrylic resins commercially available. Lucite is a trade name of DuPont for poly(methyl methacrylate) which will be described in the next subsection. Other trade names for the various acrylic resins include Acryloid, Acrysol, Acryrin, Hycar PA, Acrilan, Creslan, Dynel, Orlon, Plexiglass, Vernonite, etc. These materials are manufactured in a wide range of colors and are in demand where aesthetic considerations predominate. They possess low specific gravity, low water absorption, good weather ability, and tensile strengths but only moderate heat resistance and low hardness. They soften from 250 to 400 K and are more easily scratched than glass.

According to the Reference [A00025], the softening points of acrylics are as follows:

Acrylics	Softening Point (K)
Polymethylacrylate (PMA)	277
Polyethylacrylate (PEA)	248
Polymethylmethacrylate (PMMA)	397
Polyethylmethacrylate (PEMA)	339
Poly n-butyl methacrylate (PBMA)	303
Polyacrylonitrile	511

The polymerization of acrylate and methacrylate esters is carried out in water suspension with peroxide catalyst. The resulting polymer is washed, dried, and blended with plasticizers and colorants before pelletizing for use as molding powders.

$$CH_2=\overset{\overset{\displaystyle H}{|}}{C}-\overset{\overset{\displaystyle O}{\|}}{C}-OCH_3 \xrightarrow[\text{peroxide}\ H_2O]{80\text{-}100\ C} \left[-CH_2-\underset{\underset{\displaystyle COOCH_3}{|}}{CH}-\right]_n$$

poly(methylacrylate)

$$CH_2=\overset{\overset{\displaystyle CH_3}{|}}{C}-\overset{\overset{\displaystyle O}{\|}}{C}-OCH_3 \xrightarrow[\text{peroxide}\ H_2O]{80\text{-}100\ C} \left[-CH_2-\underset{\underset{\displaystyle COOCH_3}{|}}{CCH_3}-\right]_n$$

poly(methyl methacrylate)

Acrylic resins are soluble in aromatic and most chlorinated hydrocarbons (toluene, ethylene dichloride, chloroform), esters (ethyl acetate), ketones, tetrahydrofuran; 80/20 toluene/methanol gives low-viscosity solutions. Polymers of butyl and higher esters are

soluble in aliphatic hydrocarbons (e.g., white spirit, also in molten waxes). Cross-linked polymers are insoluble but swell in chlorinated hydrocarbons. Acrylic resins can also be swollen by alcohols, phenols, ether, and carbon tetrachloride. They are decomposable by conc. oxidizing acids (HNO_3, H_2SO_4, H_2CrO_4), alcoholic alkalis.

Acrylic resins have a density of about 1.02-1.22 g cm^{-3}. Their refractive index is about 1.47-1.49. The ultraviolet cut off is below 2800 Å, it transmits about 85% in the visible region, and the infrared cut off is about 23000 Å (2.3 μm).

a. Normal Spectral Emittance (Wavelength Dependence)

There are four sets of experimental data available for the wavelength dependence of the normal spectral emittance of acrylic resins as listed in Table 15-3 and shown in Figure 15-2. Specimen characterization and measurement information for the data are given in Table 15-2. All the data are for the paint coatings with green, blue/black, or white color. In the wavelength region above $\lambda = 6$ μm, there are small differences among the values of emittance for the different paints. In the shorter wavelength region the white paint has lowest emittance value. Since the data are limited, as a consequence, only provisional values were reported here. The provisional values listed in Table 15-1 and shown in Figure 15-1 are for the "white acrylic paint" on stainless steel substrate. The estimated uncertainty is within ± 30%.

TABLE 15-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε
WHITE PAINT ON S. STEEL T = 293		WHITE PAINT ON S. STEEL T = 293 (CONT.)	
0.32	0.953	11.00	0.934
0.36	0.935	11.50	0.944
0.37	0.799	12.00	0.952
0.40	0.508	12.50	0.958
0.45	0.372	13.00	0.962
0.50	0.264	13.50	0.956
0.65	0.275	14.00	0.944
0.80	0.275	14.50	0.928
1.00	0.320	15.00	0.900
1.50	0.465		
2.00	0.555		
2.50	0.643		
3.00	0.795		
3.20	0.863		
3.50	0.930		
3.60	0.943		
3.70	0.940		
3.80	0.880		
4.00	0.795		
4.40	0.686		
4.80	0.665		
5.00	0.665		
5.50	0.688		
5.70	0.760		
5.80	0.914		
5.90	0.926		
6.00	0.862		
6.50	0.808		
6.75	0.765		
6.80	0.876		
7.00	0.890		
7.50	0.921		
8.00	0.942		
8.50	0.923		
9.00	0.930		
9.50	0.925		
9.80	0.884		
10.00	0.880		
10.60	0.925		

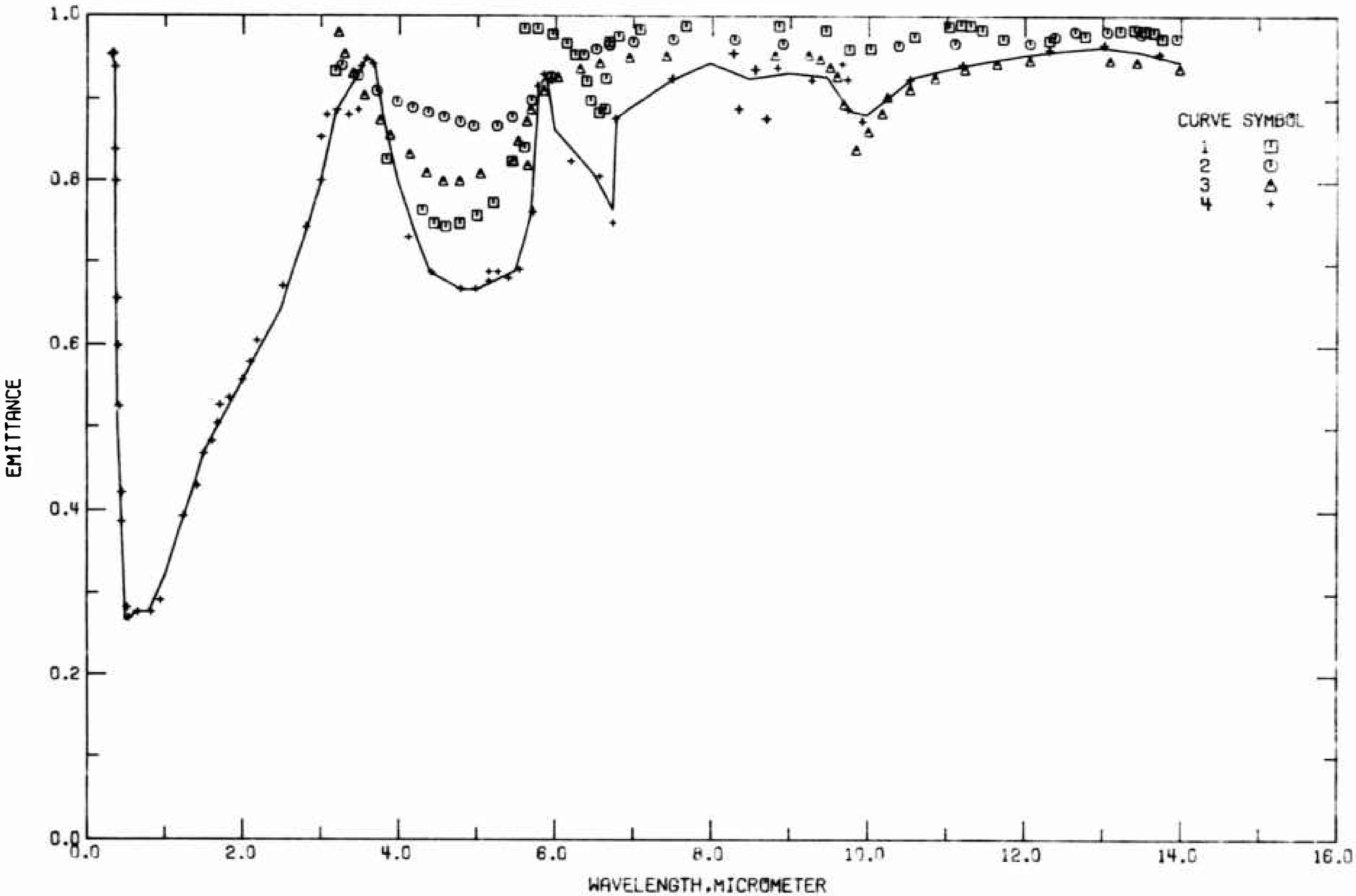


FIGURE 15-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ACRYLIC RESIN COATINGS (WAVELENGTH DEPENDENCE).

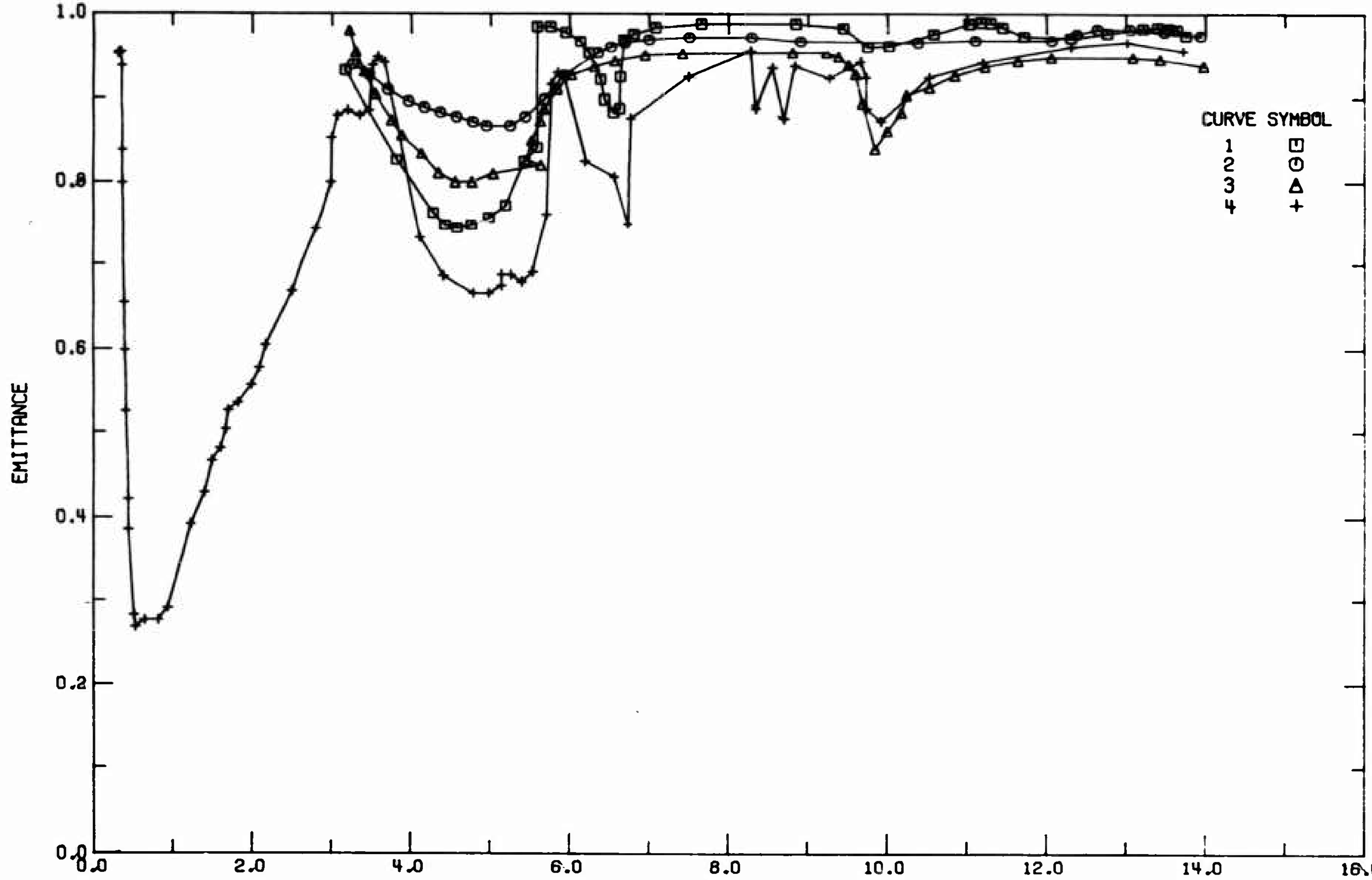


FIGURE 15-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ACRYLIC RESIN COATINGS (WAVELENGTH DEPENDENCE).

TABLE 15-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ACRYLIC RESIN COATING (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T63130	Faulkner, D., Horvath, R., Ulrich, J.P., and Work, E.	1971	3.3-14	293	MIL-L-19538B Paint (Field Green ANA-627)	Aluminum substrate, MIL-C-5541 surface preparation, MIL-C-8514 wash primer, MIL-P-7962 primer; Field Infrared Spectro-Radiometer was used; data were extracted from the figure; $\theta' \sim 0°$.
2	T63130	Faulkner, D., et al.	1971	3.3-14	293	MIL-L-19538B Blue/Black (15042) Glossy Acrylic	Similar to the above specimen.
3	T63130	Faulkner, D., et al.	1971	3.3-14	293	O.D. (X34087) Lusterless Acrylic	Similar to the above specimen.
4	T52784	Shirkle, F.J.	1961	0.3-40	~300	Flat White Acrylic Paint	7/16 in. disc stainless steel No. 301 substrate; the paint was obtained from Sherwin Williams; one coat over one coat pre-treatment wash coating; formula No. E90GC22, MIL-C-153284; $\theta' \sim 0°$.

TABLE 15-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 1	
T = 293.	
3.19	0.931
3.84	0.825
4.30	0.764
4.45	0.749
4.60	0.745
4.78	0.749
5.00	0.755
5.21	0.773
5.45	0.823
5.61	0.840
5.61	0.934
5.78	0.984
5.97	0.977
6.15	0.966
6.26	0.952
6.41	0.920
6.46	0.897
6.57	0.882
6.55	0.867
6.66	0.923
6.70	0.968
6.82	0.975
7.10	0.983
7.68	0.937
8.37	0.937
9.47	0.982
9.77	0.959
10.04	0.960
10.60	0.975
11.05	0.987
11.20	0.989
11.32	0.988
11.47	0.983
11.74	0.972
12.33	0.970
12.79	0.976
13.24	0.982
13.42	0.983
13.56	0.982

λ	ε
CURVE 1 (CONT.)	
13.67	0.980
13.78	0.973
CURVE 2	
T = 293.	
3.27	0.938
3.48	0.926
3.72	0.908
3.98	0.895
4.13	0.888
4.33	0.882
4.58	0.877
4.79	0.871
4.96	0.866
5.26	0.866
5.45	0.877
5.70	0.897
5.95	0.925
6.37	0.952
6.53	0.959
6.70	0.964
7.01	0.968
7.52	0.971
8.30	0.971
8.92	0.966
10.40	0.964
11.12	0.967
12.08	0.967
12.40	0.975
12.56	0.981
13.07	0.981
13.59	0.978
13.96	0.973
CURVE 3	
T = 293.	
3.23	0.979
3.31	0.953

λ	ε
CURVE 3 (CONT.)	
3.42	0.929
3.56	0.903
3.76	0.873
3.89	0.855
4.14	0.832
4.36	0.809
4.57	0.799
4.78	0.799
5.05	0.808
5.65	0.818
5.47	0.824
5.53	0.848
5.64	0.872
5.69	0.886
5.86	0.909
6.04	0.925
6.33	0.935
6.58	0.942
6.96	0.949
7.43	0.951
8.82	0.952
9.25	0.952
9.40	0.947
9.53	0.937
9.62	0.926
9.75	0.893
9.86	0.838
10.01	0.860
10.19	0.882
10.26	0.902
10.55	0.911
10.67	0.924
11.25	0.935
11.66	0.942
12.08	0.946
13.11	0.946
13.45	0.944
14.00	0.936

λ	ε
CURVE 4	
T = 300.	
0.316	0.951
0.329	0.953
0.348	0.953
0.352	0.936
0.365	0.837
0.373	0.798
0.393	0.655
0.402	0.596
0.414	0.524
0.443	0.421
0.444	0.385
0.516	0.281
0.532	0.267
0.652	0.275
0.819	0.275
0.940	0.290
1.233	0.392
1.407	0.429
1.500	0.466
1.637	0.481
1.675	0.503
1.706	0.526
1.828	0.535
2.000	0.557
2.099	0.578
2.183	0.604
2.512	0.669
2.812	0.744
3.006	0.799
3.006	0.852
3.076	0.879
3.236	0.885
3.357	0.879
3.483	0.885
3.524	0.937
3.589	0.947
3.673	0.940
4.122	0.732
4.416	0.586

λ	ε
CURVE 4 (CONT.)	
4.797	0.666
4.989	0.666
5.152	0.675
5.152	0.687
5.272	0.687
5.408	0.679
5.546	0.690
5.720	0.762
5.781	0.914
5.661	0.928
5.957	0.922
5.957	0.869
6.209	0.823
6.577	0.805
6.745	0.750
6.776	0.875
7.516	0.923
8.291	0.954
8.356	0.887
8.570	0.934
8.710	0.875
7.516	0.923
8.291	0.954
8.356	0.887
8.570	0.934
8.710	0.875
8.851	0.936
9.290	0.921
9.683	0.941
9.750	0.922
9.750	0.887
9.931	0.872
10.544	0.922
11.220	0.940
12.331	0.959
13.032	0.965
13.740	0.954
14.825	0.920
15.066	0.893
15.922	0.884

λ	ε
CURVE 4 (CONT.)	
17.219	0.880
17.906	0.871
20.941	0.807
21.281	0.759
21.281	0.719
21.878	0.710
22.439	0.723
22.439	0.757
23.388	0.777
24.322	0.791
25.644	0.762
26.122	0.706
27.164	0.835
28.104	0.793
28.183	0.771
29.242	0.772
33.729	0.781
34.356	0.766
35.156	0.759
37.068	0.770
37.497	0.769
37.497	0.742
38.194	0.734
39.719	0.731
97.950	0.727

b. Normal Spectral Reflectance (Wavelength Dependence)

There are thirteen sets of experimental data available for the wavelength dependence of the normal spectral reflectance of acrylic resin coatings as listed in Table 15-6 and shown in Figure 15-4. Specimen characterization and measurement information for the data are given in Table 15-5. There are seven different kinds of acrylic resins used for measurements. The normal spectral reflectance values for flat black acrylic were the lowest. White paint (Sherwin Williams) has the highest reflectance value. Only Brandenberg [T52153] and Afonaseva, et al. [T56239] measured the normal spectral reflectance in the wavelength region above 2.6 μm. Because the range of reflectance for acrylic was wide, only provisional values were reported here which are listed in Table 15-4 and shown in Figure 15-3. The provisional values are for the flat white acrylic paint (Sherwin Williams) coatings at 310 K. The estimated uncertainty is within ± 30%.

TABLE 15-[illegible]. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ
ACRYLIC PAINT WHITE T = 310		ACRYLIC PAINT WHITE T = 310 (CONT.)	
0.35	0.14	12.50	0.06
0.40	0.40	13.00	0.06
0.50	0.90	13.50	0.06
0.80	0.89	14.00	0.08
1.00	0.86	14.50	0.10
1.50	0.77	15.00	0.11
2.00	0.60		
2.50	0.45		
2.75	0.29		
3.00	0.13		
3.30	0.12		
3.50	0.09		
3.75	0.23		
3.80	0.24		
4.00	0.28		
4.40	0.33		
4.84	0.35		
5.00	0.34		
5.50	0.29		
5.70	0.12		
5.80	0.07		
6.00	0.09		
6.10	0.20		
6.30	0.25		
6.40	0.23		
6.80	0.03		
6.90	0.08		
7.00	0.09		
7.20	0.10		
7.30	0.10		
7.67	0.08		
8.00	0.07		
8.20	0.07		
9.00	0.07		
9.30	0.08		
10.00	0.10		
10.60	0.10		
11.70	0.08		
12.00	0.07		

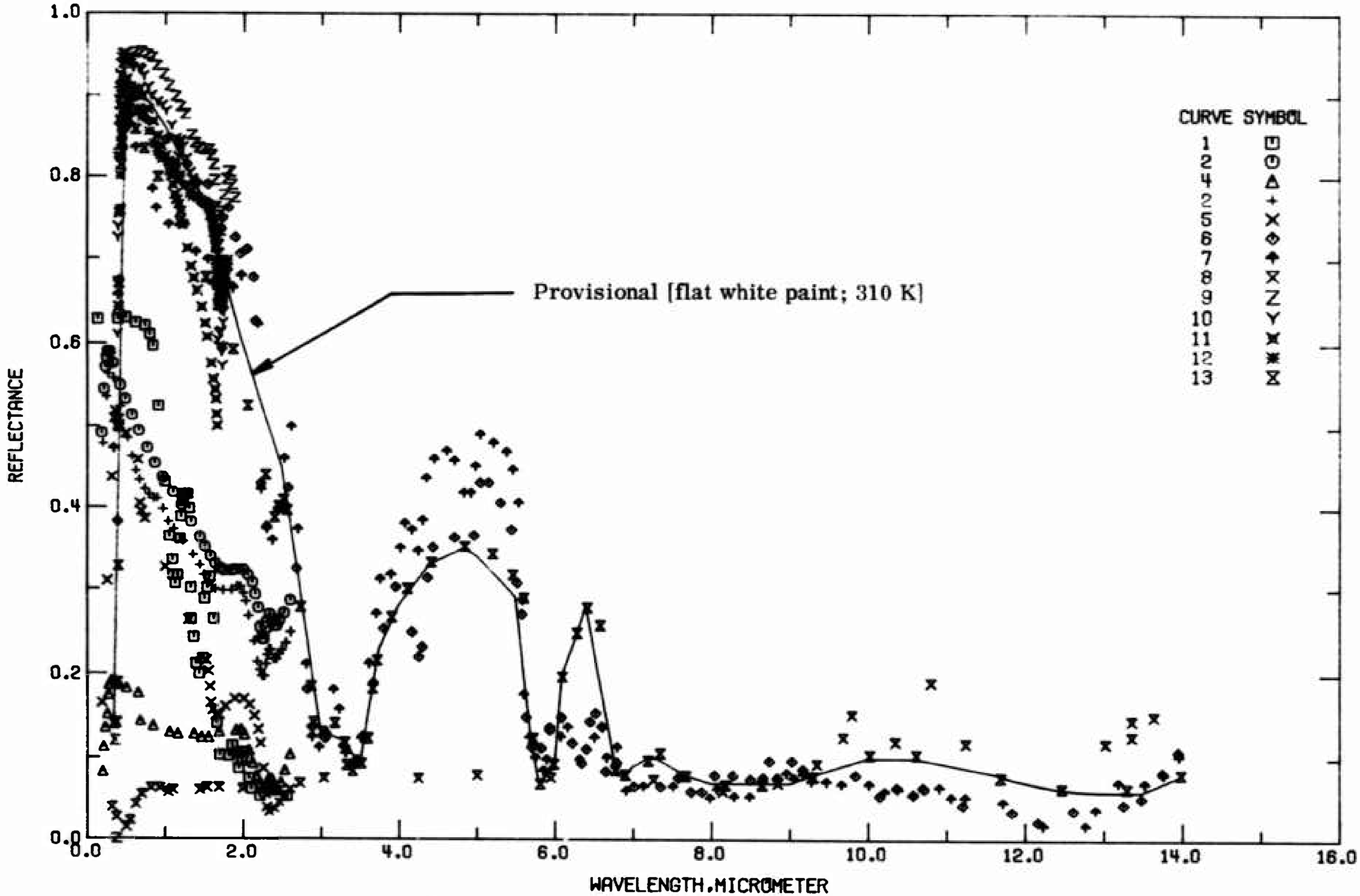


FIGURE 15-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF ACRYLIC RESIN COATINGS (WAVELENGTH DEPENDENCE).

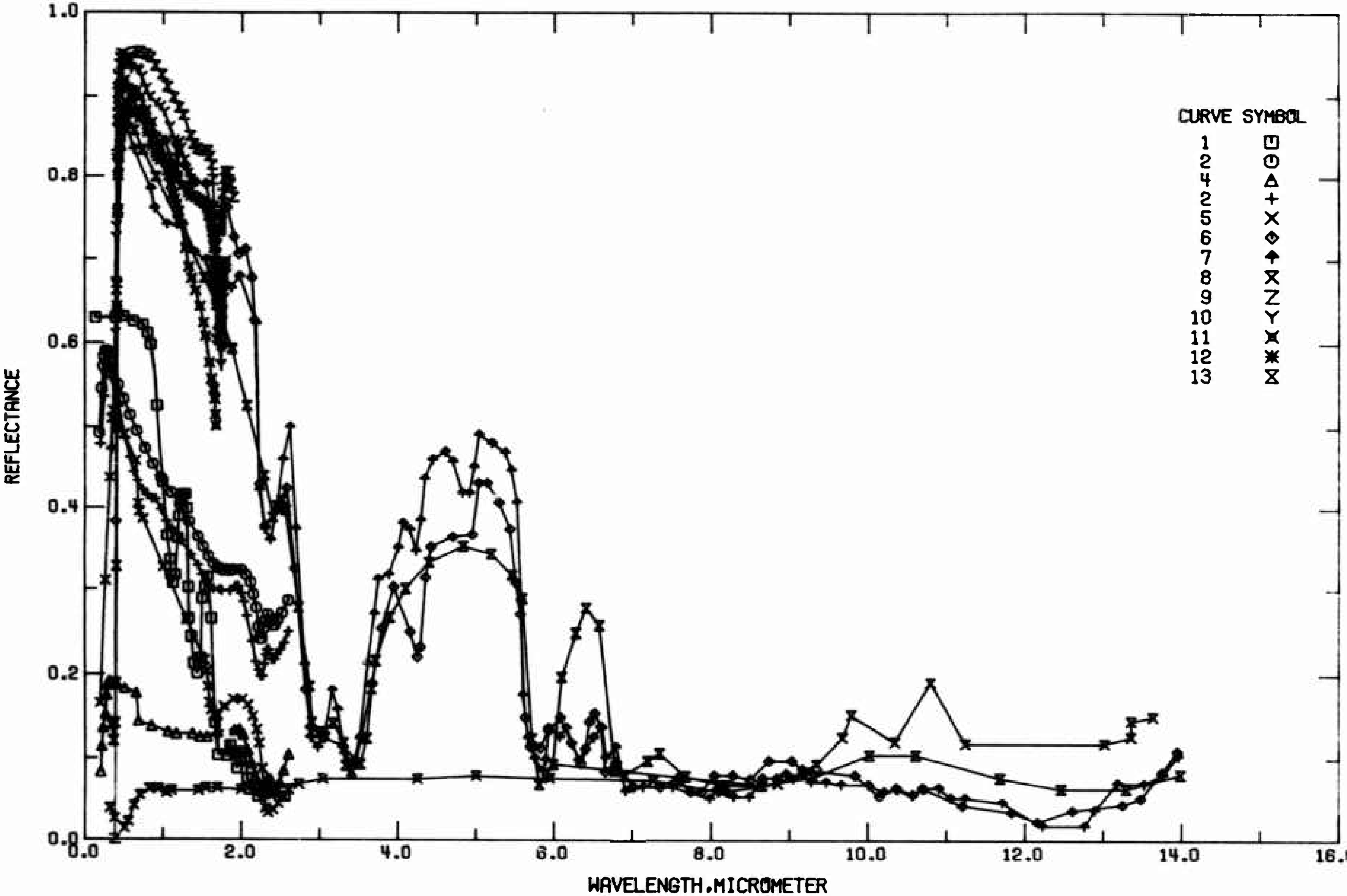


FIGURE 15-4. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ACRYLIC RESIN COATINGS (WAVELENGTH DEPENDENCE).

TABLE 15-5. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF ACRYLIC RESIN COATING (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T64206	Pennington, C.W. and Moore, G.L.	1971	0.4-2.6	~293	Acrylic Panel	Reflective type acrylic panel; reflectance spectra was measured by using a DK-2 spectrophotometer; data were extracted from figure; $\theta \sim 0°$.
2	T62587	Gilligan, J.E. and Brzuskiewicz,	1971	0.2-2.6	~293	DuPont Elvacite 6011 (methyl-methacrylate)	0.015 in. thick sprayed film; Beckman DK-2 spectrometer was used; data were extracted from figure; $\theta \sim 0°$.
3	T62587	Gilligan, J.E. and Brzuskiewicz,	1971	0.2-2.6	~293	DuPont Elvacite 6011 (methyl-methacrylate)	Similar to the above specimen except 0.032 in. thick.
4	T62587	Gilligan, J.E. and Brzuskiewicz,	1971	0.2-2.6	~293	DuPont Elvacite 6011 (methyl-methacrylate)	Similar to the above specimen except 0.054 in. thick.
5	T62587	Gilligan, J.E. and Brzuskiewicz,	1971	0.2-2.6	~293	DuPont Elvacite 6011 (methyl-methacrylate)	Similar to the above specimen except 0.035 in. thick film by a doctor's blade technique.
6	T56239	Afanaseva, G.O., Vinogradova, L.M., Illyasov, S.G., Fridzon, M.B., and Tyurin, B.F.	1969	0.25-15	~293	AS-81	Acrylic white enamals; data were extracted from figure; $\theta \sim 0°$.
7	T56239	Afanaseva, G.O., et al.	1969	0.25-15	~293	AS-2Cp (R)	Similar to the above specimen.
8	T53498	Shinkle, F.J.	1961	0.38-38	338	Flat Black Acrylic Paint	A heavy coat of paint had been sprayed on 5/16 in. diameter disc of 0.012 in. thick stainless steel; a Perkin-Elmer Model 13 double beam spectrometer was used; data were extracted from figure; $\theta \sim 0°$.
9	T39754	Anderson, R.B.	1965	0.38-1.9	~293	(Sherwin Williams) White Paint	3 mil spray coating of W. P. Fuller Co. 171W-560 Acrylic Vehicle glass white paint on a white substrate; a Gier-Dunkel reflectometer and a Cary reflectometer were used; data were extracted from figure; $\theta \sim 0°$.
10	T39754	Anderson, R.B.	1965	0.38-1.9	~293	White Paint (DMS 1765)	2.6 mil spray coating of DMS 1765 white paint on aluminum; other specifications similar to above.
11	T39754	Anderson, R.B.	1965	0.38-1.9	~293	White Paint (NASA-S-13)	8.5 mil spray coating of NASA-S-13 white paint on aluminum; other specifications similar to above.
12	T39754	Anderson, R.B.	1965	0.38-1.9	~293	White Paint (MIL-C22750)	2.2 mil spray coating of MIL-C22750 white paint on aluminum; other specifications similar to above.
13	T52153	Bradenberg, W.M.	1961	0.3-25	310.8	Flat White Acrylic Paint	Two coats of Sherwin Williams Flat White acrylic paint over one coat of Sherwin Williams Pre-treatment Wash coating were coated on vehicle; Perkin-Elmer Model 13 double beam meter was used; data were extracted from figure; $\theta \sim 0°$.

TABLE 15-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

CURVE 1
T = 293.

λ	ρ
0.400	0.628
0.140	0.628
0.500	0.630
0.530	0.624
0.750	0.620
0.811	0.610
0.847	0.596
3.871	0.560
0.919	0.524
0.996	0.431
1.055	0.364
1.0941	0.335
1.104	0.316
1.13	0.306
1.159	0.316
1.189	0.361
1.205	0.383
1.228	0.407
1.253	0.416
1.288	0.416
1.309	0.398
1.328	0.301
1.334	0.264
1.365	0.243
1.397	0.212
1.439	0.200
1.486	0.218
1.507	0.268
1.538	0.301
1.574	0.314
1.622	0.264
1.664	0.141
1.702	0.103
1.787	0.900
1.820	0.102
1.862	0.114
1.919	0.105
1.945	0.087
1.986	0.096

CURVE 1 (CONT.)

λ	ρ
1.996	0.106
2.056	0.099
2.080	0.075
2.109	0.062
2.219	0.053
2.559	0.053

CURVE 2
T = 293.

λ	ρ
0.186	0.491
0.215	0.544
0.236	0.570
0.250	0.582
0.269	0.589
0.289	0.589
0.328	0.575
0.426	0.549
0.493	0.532
0.575	0.513
0.663	0.494
0.771	0.473
0.671	0.454
0.973	0.437
1.103	0.418
1.214	0.402
1.331	0.382
1.447	0.363
1.511	0.351
1.581	0.339
1.641	0.330
1.707	0.324
1.755	0.321
1.856	0.321
1.902	0.322
2.002	0.322
2.060	0.316
2.118	0.307
2.158	0.293
2.194	0.277

CURVE 2 (CONT.)

λ	ρ
2.220	0.254
2.242	0.241
2.266	0.241
2.293	0.253
2.310	0.261
2.342	0.269
2.378	0.261
2.405	0.256
2.428	0.256
2.470	0.263
2.526	0.271
2.600	0.286

CURVE 3
T = 293.

λ	ρ
0.200	0.083
0.211	0.113
0.229	0.135
0.259	0.151
0.274	0.174
0.286	0.186
0.308	0.191
0.412	0.186
0.507	0.182
0.655	0.176
0.682	0.143
0.846	0.137
1.057	0.130
1.163	0.128
1.371	0.128
1.469	0.124
1.558	0.124
1.694	0.130
1.914	0.132
1.978	0.133
2.021	0.127
2.079	0.109
2.127	0.093
2.177	0.078

CURVE 3 (CONT.)

λ	ρ
2.218	0.069
2.260	0.063
2.293	0.063
2.335	0.074
2.367	0.074
2.408	0.060
2.452	0.060
2.490	0.070
2.538	0.085
2.600	0.104

CURVE 4
T = 293.

λ	ρ
0.200	0.478
0.247	0.535
0.268	0.562
0.284	0.572
0.297	0.572
0.338	0.557
0.426	0.523
0.519	0.485
0.575	0.462
0.622	0.444
0.670	0.433
0.738	0.422
0.796	0.415
0.855	0.410
0.898	0.410
0.970	0.397
1.039	0.382
1.111	0.373
1.228	0.358
1.354	0.341
1.444	0.328
1.499	0.316
1.559	0.307
1.641	0.299
1.742	0.297
1.854	0.297

CURVE 4 (CONT.)

λ	ρ
1.919	0.302
1.961	0.302
2.002	0.294
2.038	0.284
2.071	0.267
2.142	0.238
2.185	0.214
2.222	0.204
2.247	0.197
2.273	0.197
2.295	0.211
2.317	0.222
2.333	0.228
2.352	0.228
2.393	0.217
2.427	0.217
2.459	0.223
2.500	0.228
2.550	0.236
2.600	0.249

CURVE 5
T = 293.

λ	ρ
0.193	0.164
0.261	0.309
0.318	0.437
0.349	0.509
0.365	0.518
0.493	0.490
0.650	0.458
0.678	0.404
0.697	0.394
0.741	0.385
1.005	0.326
1.303	0.263
1.529	0.216
1.557	0.203
1.578	0.184
1.594	0.165

CURVE 5 (CONT.)

λ	ρ
1.615	0.156
1.653	0.150
1.695	0.150
1.776	0.160
1.898	0.169
2.016	0.169
2.086	0.162
2.151	0.149
2.1976	0.133
2.227	0.117
2.267	0.087
2.298	0.055
2.312	0.039
2.338	0.033
2.405	0.037
2.470	0.045
2.531	0.053
2.600	0.062

CURVE 6
T = 293.

λ	ρ
0.39	0.382
0.41	0.672
0.47	0.876
0.51	0.887
0.59	0.895
0.76	0.868
1.02	0.843
1.13	0.813
1.28	0.813
1.41	0.791
1.55	0.789
1.62	0.746
1.65	0.729
1.72	0.734
1.74	0.747
1.82	0.760
1.91	0.724
1.97	0.704

TABLE 15-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
CURVE	6 (CONT.)	CURVE	6 (CONT.)	CURVE	7 (CONT.)	CURVE	7 (CONT.)	CURVE	7 (CONT.)	CURVE	8 (CONT.)
2.06	0.710	6.60	0.137	0.45	0.831	4.35	0.436	9.47	0.072	0.819	0.063
2.14	0.676	6.65	0.084	0.53	0.859	4.45	0.460	9.66	0.069	0.935	0.063
2.17	0.626	6.79	0.095	0.62	0.833	4.61	0.470	10.01	0.069	1.042	0.058
2.23	0.429	7.01	0.066	0.84	0.783	4.71	0.458	10.21	0.060	1.104	0.051
2.30	0.376	7.35	0.066	0.89	0.759	4.83	0.418	10.38	0.063	1.449	0.061
2.47	0.393	7.58	0.077	1.05	0.739	4.92	0.418	10.57	0.056	1.538	0.064
2.58	0.424	7.74	0.060	1.25	0.739	4.98	0.451	10.70	0.065	1.690	0.064
2.68	0.324	7.88	0.060	1.40	0.706	5.04	0.490	10.91	0.065	1.995	0.062
2.82	0.131	8.04	0.080	1.55	0.697	5.21	0.480	11.06	0.053	2.366	0.065
2.88	0.136	8.28	0.080	1.62	0.668	5.38	0.469	11.24	0.053	2.730	0.069
3.05	0.123	8.50	0.075	1.69	0.644	5.46	0.447	11.72	0.047	3.034	0.075
3.29	0.114	8.74	0.097	1.78	0.664	5.53	0.406	12.23	0.018	4.246	0.075
3.46	0.097	9.03	0.097	1.87	0.664	5.58	0.287	12.77	0.018	5.000	0.079
3.53	0.125	9.17	0.087	1.98	0.678	5.60	0.175	12.90	0.038	5.943	0.076
3.67	0.189	9.84	0.030	2.19	0.622	5.67	0.124	13.19	0.071	7.261	0.074
3.80	0.253	10.15	0.055	2.23	0.422	5.75	0.100	13.53	0.070	8.148	0.060
3.95	0.302	10.37	0.065	2.30	0.373	5.85	0.085	13.77	0.081	8.851	0.070
4.16	0.249	10.58	0.057	2.37	0.359	5.89	0.098	13.97	0.103	9.351	0.093
4.25	0.220	10.72	0.064	2.45	0.398	5.93	0.136	14.07	0.096	9.683	0.124
4.29	0.232	11.21	0.043	2.53	0.460	6.07	0.125	14.11	0.116	9.795	0.151
4.36	0.313	11.84	0.035	2.62	0.499	6.16	0.136	14.18	0.127	10.35	0.119
4.43	0.351	12.17	0.023	2.70	0.373	6.31	0.098	14.35	0.127	10.81	0.190
4.71	0.363	12.62	0.037	2.81	0.211	6.50	0.124	14.41	0.156	11.25	0.117
4.96	0.366	13.26	0.044	2.88	0.124	6.61	0.136	14.49	0.192	13.03	0.117
5.04	0.431	13.49	0.052	2.97	0.112	6.66	0.101	14.54	0.192	13.37	0.125
5.15	0.431	13.76	0.083	3.06	0.128	6.79	0.113	14.64	0.182	13.37	0.144
5.30	0.406	13.96	0.108	3.16	0.180	6.91	0.061	14.79	0.220	13.65	0.149
5.44	0.373	14.11	0.091	3.23	0.157	7.13	0.066	14.89	0.253	14.16	0.130
5.51	0.307	14.31	0.082	3.31	0.105	7.51	0.066	14.97	0.198	14.16	0.089
5.57	0.270	14.44	0.092	3.43	0.093	7.98	0.052	15.06	0.178	14.52	0.080
5.63	0.148	14.61	0.093	3.51	0.123	8.07	0.063			14.79	0.091
5.70	0.113	14.79	0.125	3.61	0.212	8.16	0.063	CURVE 8		14.93	0.116
5.82	0.112	14.91	0.148	3.70	0.270	8.29	0.054	T = 338.		15.32	0.124
5.93	0.133	15.05	0.179	3.75	0.311	8.49	0.054			16.00	0.117
6.08	0.148			3.89	0.317	8.66	0.077	0.321	0.039	16.79	0.127
6.22	0.118	CURVE 7		4.01	0.350	8.84	0.077	0.378	0.026	17.86	0.177
6.34	0.094	T = 293.		4.07	0.380	8.96	0.082	0.504	0.014	18.75	0.213
6.40	0.111			4.16	0.372	9.05	0.076	0.552	0.022	19.23	0.221
6.45	0.143	0.34	0.472	4.24	0.346	9.17	0.081	0.625	0.042	20.14	0.221
6.52	0.153	0.40	0.656	4.30	0.384	9.28	0.072	0.702	0.055	22.44	0.170

TABLE 15-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 8 (CONT.)	
24.55	0.143
26.36	0.156
27.23	0.187
27.86	0.230
28.38	0.266
28.71	0.349
29.17	0.357
30.69	0.343
31.55	0.385
32.36	0.376
33.04	0.363
34.51	0.384
37.27	0.384
CURVE 9	
T = 293.	
0.380	0.000
0.399	0.498
0.405	0.670
0.412	0.825
0.423	0.877
0.423	0.902
0.438	0.920
0.466	0.937
0.500	0.941
0.565	0.943
0.616	0.951
0.700	0.952
0.783	0.949
0.840	0.945
0.900	0.935
0.987	0.924
1.057	0.910
1.140	0.897
1.200	0.884
1.263	0.875
1.346	0.849
1.388	0.839
1.441	0.833

λ	ρ
CURVE 9 (CONT.)	
1.503	0.831
1.569	0.831
1.601	0.824
1.625	0.813
1.641	0.794
1.652	0.761
1.661	0.733
1.679	0.715
1.692	0.715
1.713	0.732
1.736	0.755
1.769	0.776
1.797	0.795
1.817	0.804
1.841	0.804
1.867	0.789
1.900	0.773
CURVE 10	
T = 293.	
0.386	0.500
0.389	0.610
0.396	0.724
0.400	0.737
0.405	0.821
0.410	0.858
0.417	0.892
0.421	0.908
0.427	0.924
0.436	0.937
0.448	0.945
0.464	0.950
0.497	0.950
0.523	0.945
0.549	0.937
0.592	0.931
0.663	0.931
0.689	0.929
0.725	0.922

λ	ρ
CURVE 10 (CONT.)	
0.784	0.908
0.826	0.898
0.903	0.890
0.963	0.886
1.011	0.879
1.083	0.861
1.142	0.844
1.167	0.834
1.175	0.822
1.179	0.799
1.182	0.794
1.192	0.831
1.195	0.840
1.202	0.842
1.229	0.834
1.278	0.820
1.323	0.803
1.353	0.795
1.367	0.785
1.382	0.774
1.440	0.768
1.502	0.765
1.527	0.762
1.548	0.759
1.566	0.754
1.602	0.741
1.627	0.728
1.644	0.720
1.660	0.711
1.674	0.703
1.679	0.695
1.682	0.603
1.698	0.595
1.705	0.611
1.705	0.642
1.709	0.650
1.712	0.671
1.718	0.667
1.720	0.638
1.725	0.614

λ	ρ
CURVE 10 (CONT.)	
1.733	0.588
1.740	0.572
1.746	0.594
1.751	0.624
1.757	0.636
1.759	0.657
1.764	0.661
1.770	0.659
1.778	0.651
1.784	0.665
1.800	0.680
CURVE 11	
T = 293.	
0.404	0.501
0.411	0.642
0.418	0.753
0.423	0.868
0.430	0.885
0.440	0.898
0.458	0.909
0.476	0.915
0.505	0.918
0.550	0.908
0.597	0.905
0.658	0.905
0.704	0.897
0.779	0.881
0.848	0.866
0.902	0.848
0.952	0.835
1.004	0.823
1.060	0.805
1.081	0.799
1.103	0.788
1.127	0.776
1.148	0.770
1.180	0.764
1.204	0.755

λ	ρ
CURVE 11 (CONT.)	
1.234	0.739
1.292	0.711
1.335	0.689
1.370	0.675
1.419	0.661
1.475	0.642
1.521	0.623
1.549	0.607
1.595	0.575
1.624	0.556
1.648	0.544
1.661	0.532
1.669	0.514
1.671	0.500
CURVE 12	
T = 293.	
0.404	0.501
0.411	0.642
0.418	0.753
0.425	0.799
0.433	0.822
0.439	0.836
0.448	0.849
0.460	0.863
0.474	0.873
0.488	0.878
0.507	0.881
0.524	0.881
0.646	0.881
0.667	0.878
0.702	0.871
0.796	0.853
0.862	0.837
0.902	0.828
0.928	0.823
0.964	0.819
1.043	0.816
1.068	0.812

λ	ρ
CURVE 12 (CONT.)	
1.127	0.804
1.177	0.797
1.259	0.787
1.325	0.778
1.358	0.774
1.420	0.772
1.462	0.769
1.503	0.767
1.530	0.765
1.549	0.764
1.565	0.759
1.589	0.750
1.615	0.742
1.639	0.730
1.650	0.724
1.658	0.711
1.659	0.696
1.667	0.687
1.672	0.676
1.685	0.666
1.701	0.657
1.711	0.652
1.724	0.649
1.730	0.649
1.740	0.653
1.742	0.667
1.749	0.671
1.760	0.673
1.768	0.679
1.777	0.688
1.787	0.693
1.800	0.696
CURVE 13	
T = 293.	
0.341	0.139
0.362	0.120
0.382	0.141
0.393	0.189

TABLE 15-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ
CURVE 13 (CONT.)		CURVE 13 (CONT.)		CURVE 13 (CONT.)	
0.401	0.327	5.715	0.123	19.634	0.143
0.406	0.507	5.808	0.069	19.953	0.183
0.427	0.757	5.984	0.093	20.701	0.215
0.433	0.812	6.095	0.197	21.528	0.236
0.444	0.839	6.280	0.248	22.856	0.248
0.460	0.859	6.412	0.278	24.210	0.235
0.493	0.868	6.577	0.257	25.941	0.200
0.542	0.868	6.776	0.086	100.00	0.200
0.624	0.856	6.902	0.080		
0.738	0.832	7.195	0.097		
0.912	0.798	7.345	0.106		
1.189	0.743	7.674	0.079		
1.531	0.676	8.1846	0.068		
1.683	0.644	8.650	0.068		
1.879	0.592	5.984	0.093		
2.065	0.525	6.095	0.197		
2.291	0.440	6.281	0.248		
2.404	0.387	6.412	0.278		
2.455	0.401	6.577	0.257		
2.518	0.409	6.776	0.086		
2.565	0.396	6.9024	0.080		
2.735	0.278	7.195	0.097		
2.871	0.185	7.345	0.106		
2.904	0.142	7.674	0.079		
3.013	0.130	8.185	0.068		
3.177	0.141	8.650	0.068		
3.304	0.118	9.311	0.078		
3.327	0.091	10.023	0.104		
3.404	0.084	10.617	0.104		
3.516	0.093	11.695	0.077		
3.598	0.123	12.473	0.064		
3.664	0.182	13.305	0.064		
3.715	0.216	13.996	0.081		
3.899	0.266	14.555	0.105		
4.102	0.300	15.066	0.116		
4.406	0.332	15.922	0.105		
4.842	0.352	16.673	0.095		
5.200	0.343	17.418	0.095		
5.458	0.317	18.535	0.107		
5.598	0.289	19.187	0.127		

c. Normal Spectral Absorptance (Wavelength Dependence)

There are five sets of experimental data available for the wavelength dependence of the normal spectral absorptance of acrylic resin coatings as listed in Table 15-9 and shown in Figure 15-6. Specimen characterization and measurement information for the data are given in Table 15-8. Four of the data sets each contains a single point (10.6 μm). Therefore, as a consequence of the limited data, only provisional values of normal spectral emittance are presented here as listed in Table 15-7 and shown in Figure 15-5. The provisional values are for the "white acrylic paint" on stainless steel substrate. The estimated uncertainty is within ±30%.

TABLE 15-7. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α)

λ	α	λ	α
WHITE PAINT S. STEEL SUBSTRA T = 293		WHITE PAINT S. STEEL SUBSTRA T = 293 (CONT.)	
0.32	0.953	11.00	0.934
0.36	0.936	11.50	0.944
0.37	0.793	12.00	0.952
0.40	0.508	12.50	0.955
0.45	0.372	13.00	0.962
0.50	0.264	13.50	0.956
0.65	0.275	14.00	0.944
0.80	0.275	14.50	0.928
1.00	0.320	15.00	0.900
1.50	0.465		
2.00	0.555		
2.50	0.643		
3.00	0.795		
3.20	0.883		
3.50	0.930		
3.60	0.948		
3.70	0.940		
3.80	0.880		
4.00	0.795		
4.40	0.686		
4.80	0.665		
5.00	0.665		
5.50	0.689		
5.70	0.760		
5.80	0.914		
5.90	0.926		
6.00	0.862		
6.50	0.808		
6.75	0.765		
6.80	0.876		
7.00	0.890		
7.50	0.921		
8.00	0.942		
8.50	0.923		
9.00	0.930		
9.50	0.925		
9.80	0.884		
10.00	0.880		
10.60	0.925		

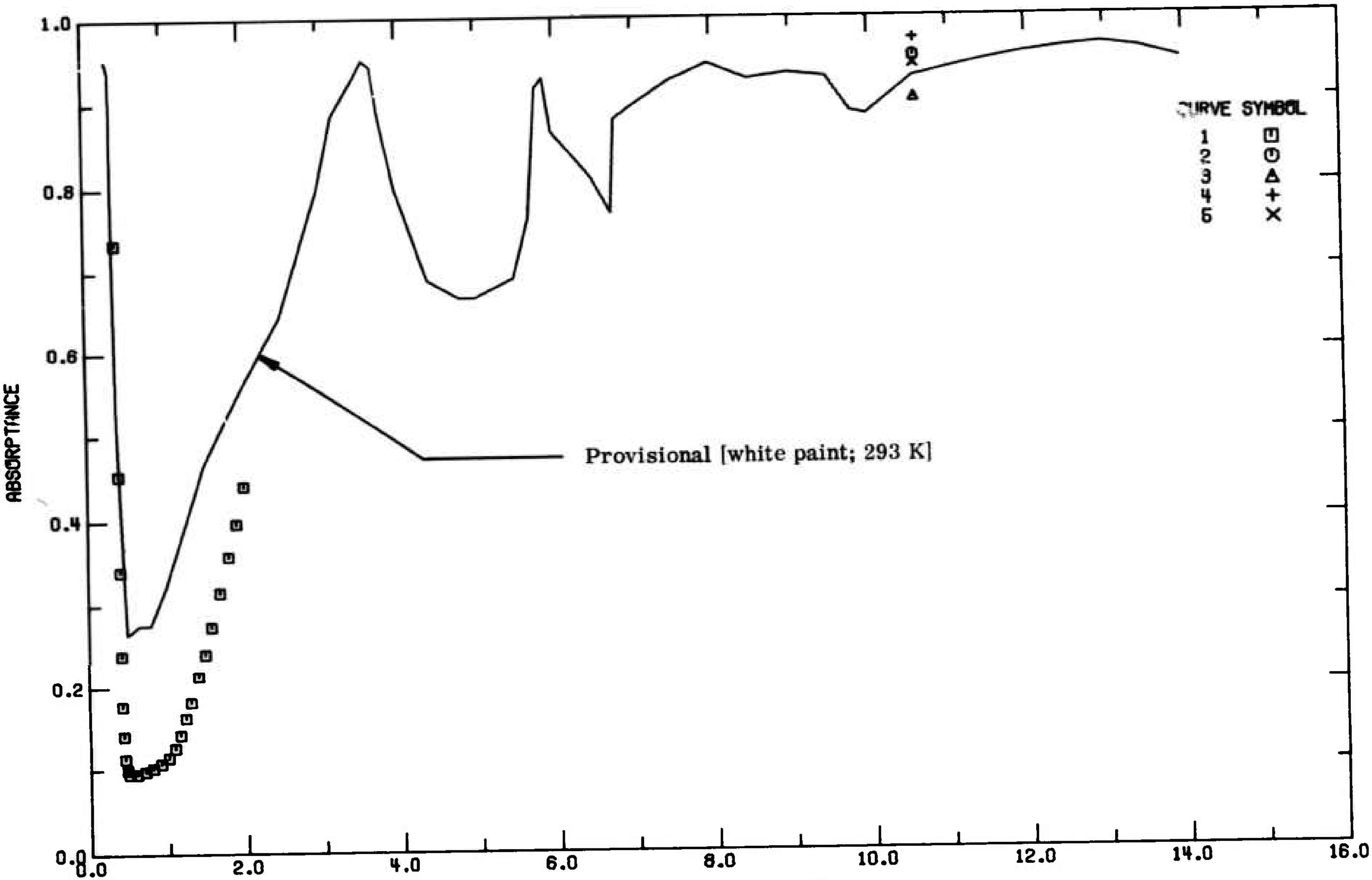


FIGURE 15-5. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF ACRYLIC RESIN COATINGS (WAVELENGTH DEPENDENCE).

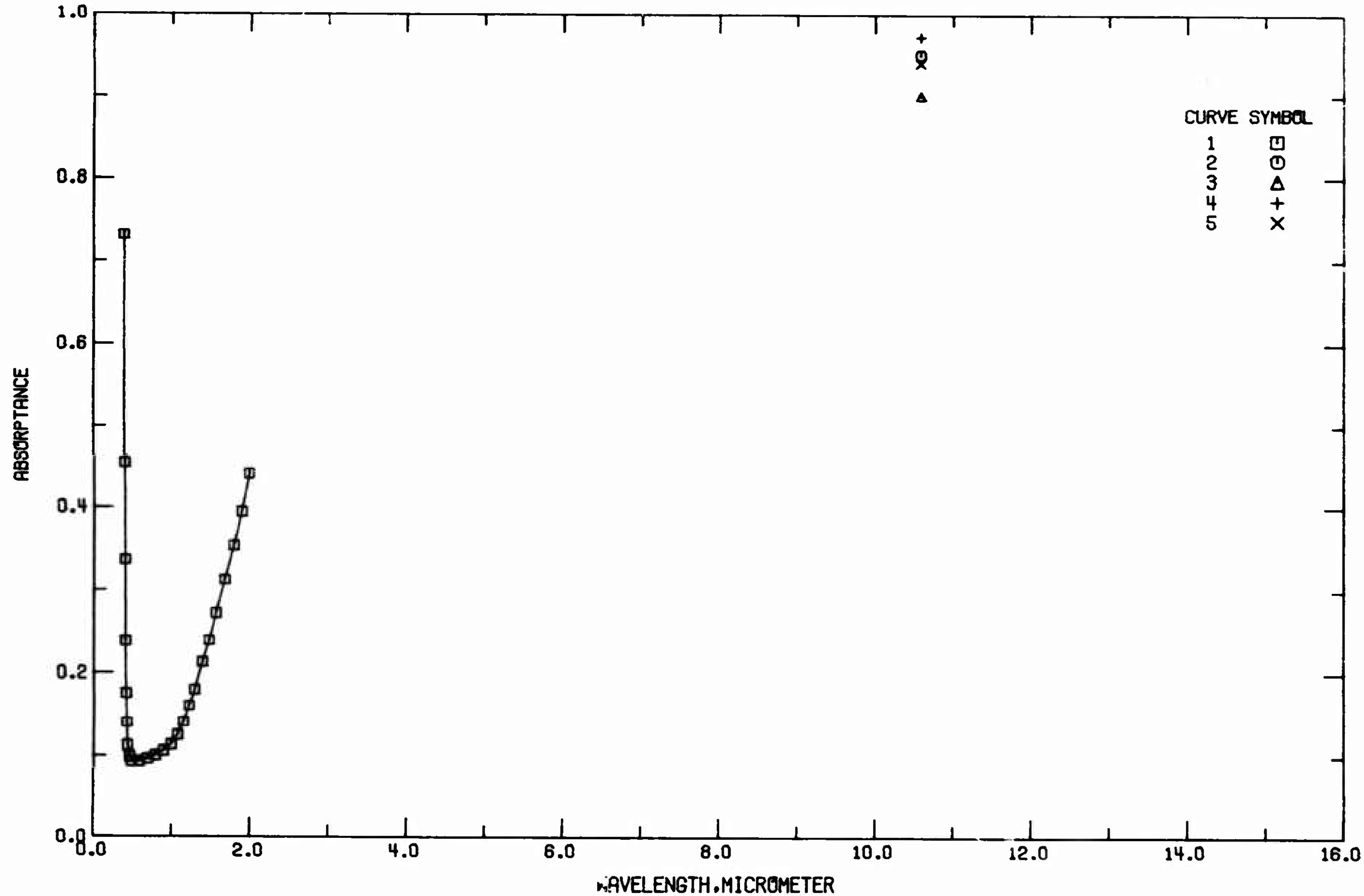


FIGURE 15-6. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF ACRYLIC RESIN COATINGS (WAVELENGTH DEPENDENCE).

TABLE 15-8. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF ACRYLIC RESIN COATING (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T39754	Anderson, R. B.	1965	0.38-2.0	~293	White Paint	3 mil spray coating of W. P. Fuller Co. 171W-560 Acrylic Vehicle gloss white paint on a white substrate; data were extracted from figure; $\theta \sim 0°$.
2	A00004	Firsdon, R.	1968	10.6	300	Acrylic (black)	Acrylic-Mil-L-19538B-black; Mil-P-7968 0.7 mil thick primer; 3.0 mil thick top coat; an IR-9 Beckman spectrometer was used for measurements.
3	A00004	Firsdon, R.	1968	10.6	300	Acrylic (black)	The above specimen; a calorimeter was used for measurements.
4	A00004	Firsdon, R.	1968	10.6	300	Acrylic (white)	Acrylic-Mil-C-81352-white; Mil-P-23377-0.5 mil thick primer; 1.7 mil thick top coat; an IR-9 Beckman spectrometer was used.
5	A00004	Firsdon, R.	1968	10.6	300	Acrylic (white)	The above specimen; a calorimeter was used for measurements.

TABLE 15-9. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α)

λ	α	λ	α
CURVE 1		CURVE 4	
T = 293.		T = 300.	
0.400	0.732	10.6	0.97
0.404	0.453		
0.409	0.338	CURVE 5	
0.415	0.239	T = 300.	
0.420	0.176		
0.432	0.139	10.6	0.94
0.446	0.112		
0.469	0.099		
0.495	0.094		
0.592	0.094		
0.701	0.097		
0.800	0.101		
0.903	0.105		
1.000	0.113		
1.086	0.124		
1.155	0.140		
1.229	0.161		
1.298	0.181		
1.399	0.213		
1.482	0.243		
1.571	0.273		
1.684	0.313		
1.801	0.356		
1.902	0.395		
2.000	0.440		
CURVE 2			
T = 300.			
10.6	0.95		
CURVE 3			
T = 300.			
10.6	0.98		

d. Normal Spectral Absorptance (Temperature Dependence)

There is no experimental data available for the temperature dependence of the normal spectral absorptance of acrylic resins. However, Frisdon [A00004] measured the absorptance of acrylic paints as a function of the incident power of CO_2 laser. His results show that there is very small decreasing or no change in the absorptance value for the incident power of CO_2 laser up to 130 watts. As the incident power equals to 60 watts or higher, there is instantaneous surface charring happening at the point of incidence. Probably this charring occurs at the decomposing temperature. Therefore, we can roughly say that the absorptance of acrylic paints at wavelength 10.6 μm is independent of temperature in the temperature region from 293 K to 400 K (decomposing temperature). Figure 15-7 shows the provisional value for the normal spectral absorptance of acrylic white and black paints as a function of temperature.

The absorptance is 0.97 for white paint and 0.95 for black paint. The estimated uncertainty is within ±20%.

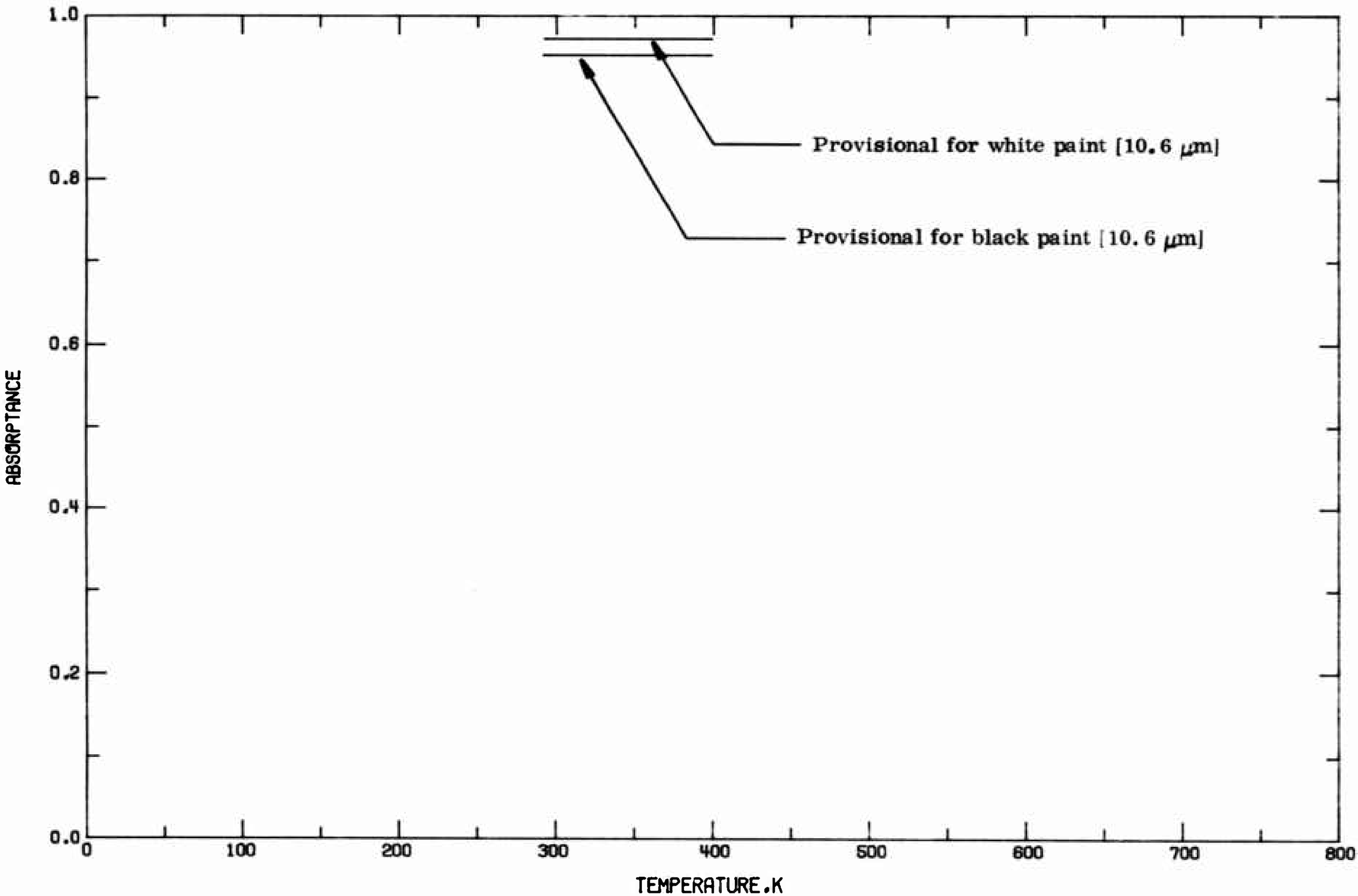


FIGURE 15-7. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF ACRYLIC RESIN COATING (TEMPERATURE DEPENDENCE)

e. Normal Spectral Transmittance (Wavelength Dependence)

There are 30 sets of experimental data available for the wavelength dependence of the normal spectral transmittance of acrylic resins as listed in Table 15-12 and shown in Figure 15-8 (bulk materials) and Figure 15-9 (thin films). Specimen characterization and measurement information for the data are given in Table 15-11. There were 20 different kinds of acrylic resins used for measurement; their transmittance values were quite different. Therefore, only provisional values are reported here as listed in Table 15-10 and shown in Figure 15-7. The provisional values are for the acrylic sheet with thickness 6.3 mm at 293 K. The estimated uncertainty is within ±30%.

TABLE 15-10. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ	λ	τ
ACRYLIC SHEET 6.3MM THICK T = 293		ACRYLIC SHEET 6.3MM THICK T = 293 (CONT.)	
0.42	0.82	1.50	0.61
0.43	0.81	1.54	0.61
0.45	0.81	1.59	0.60
0.47	0.80	1.62	0.59
0.49	0.81	1.64	0.59
0.50	0.83	1.70	0.54
0.51	0.83	1.74	0.50
0.62	0.83	1.76	0.48
0.64	0.84	1.79	0.46
0.64	0.85	1.81	0.45
0.66	0.86	1.84	0.45
0.68	0.88	1.85	0.49
0.69	0.90	1.87	0.47
0.71	0.92	1.88	0.49
0.72	0.92	1.89	0.51
0.75	0.92	1.91	0.53
0.77	0.92	1.92	0.57
0.81	0.91	1.94	0.63
0.84	0.90	1.95	0.68
0.88	0.89	1.96	0.71
0.91	0.88	1.97	0.73
0.94	0.88	1.98	0.76
0.98	0.89	2.00	0.77
1.03	0.89	2.01	0.79
1.07	0.90	2.03	0.80
1.10	0.90	2.05	0.80
1.13	0.89	2.09	0.81
1.17	0.89	2.16	0.82
1.20	0.88	2.31	0.82
1.22	0.87	2.51	0.83
1.24	0.85		
1.26	0.84		
1.29	0.82		
1.32	0.75		
1.35	0.71		
1.38	0.66		
1.41	0.64		
1.43	0.63		
1.46	0.62		

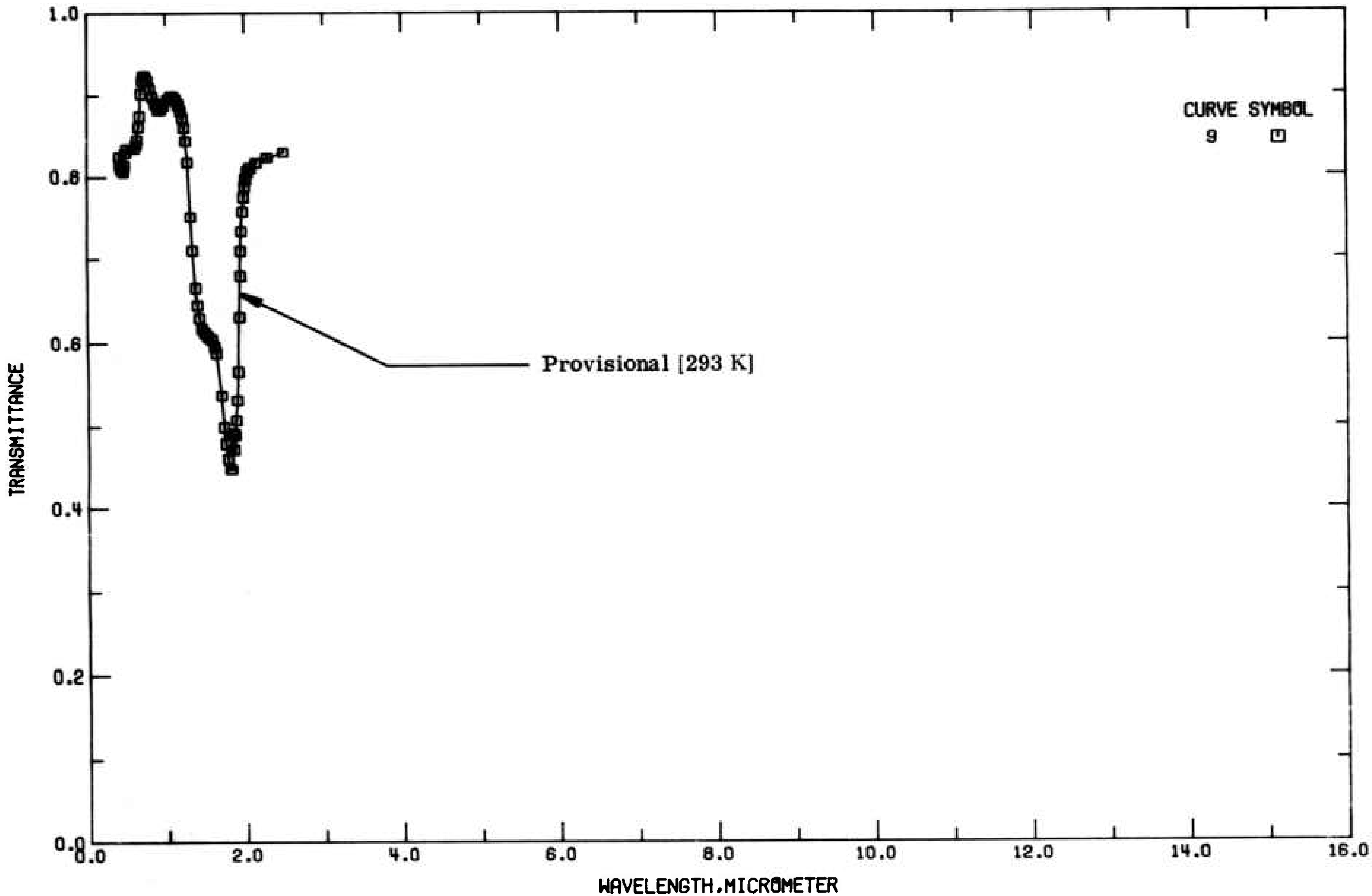


FIGURE 15-8. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE).

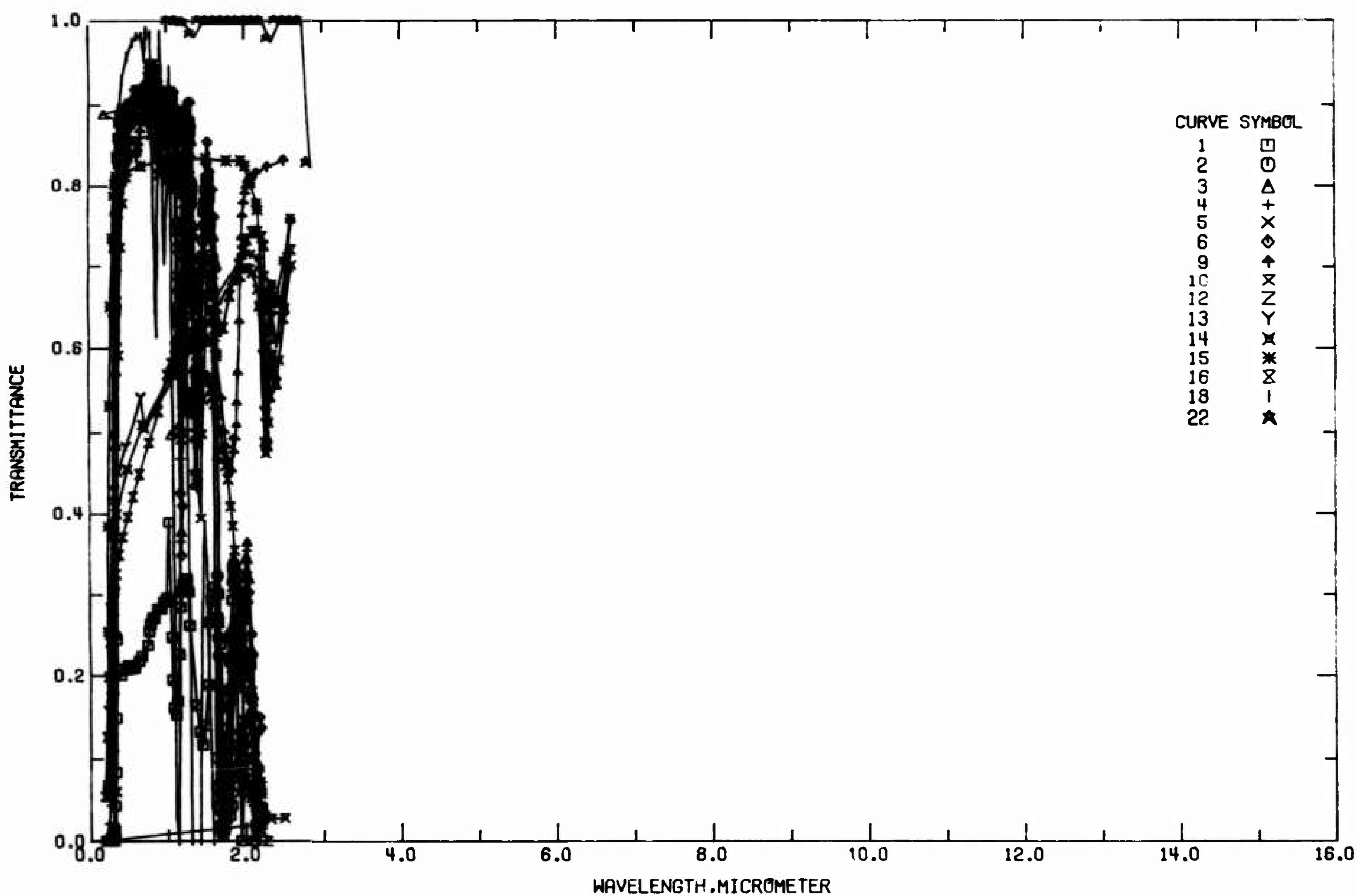


FIGURE 15-9. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE).

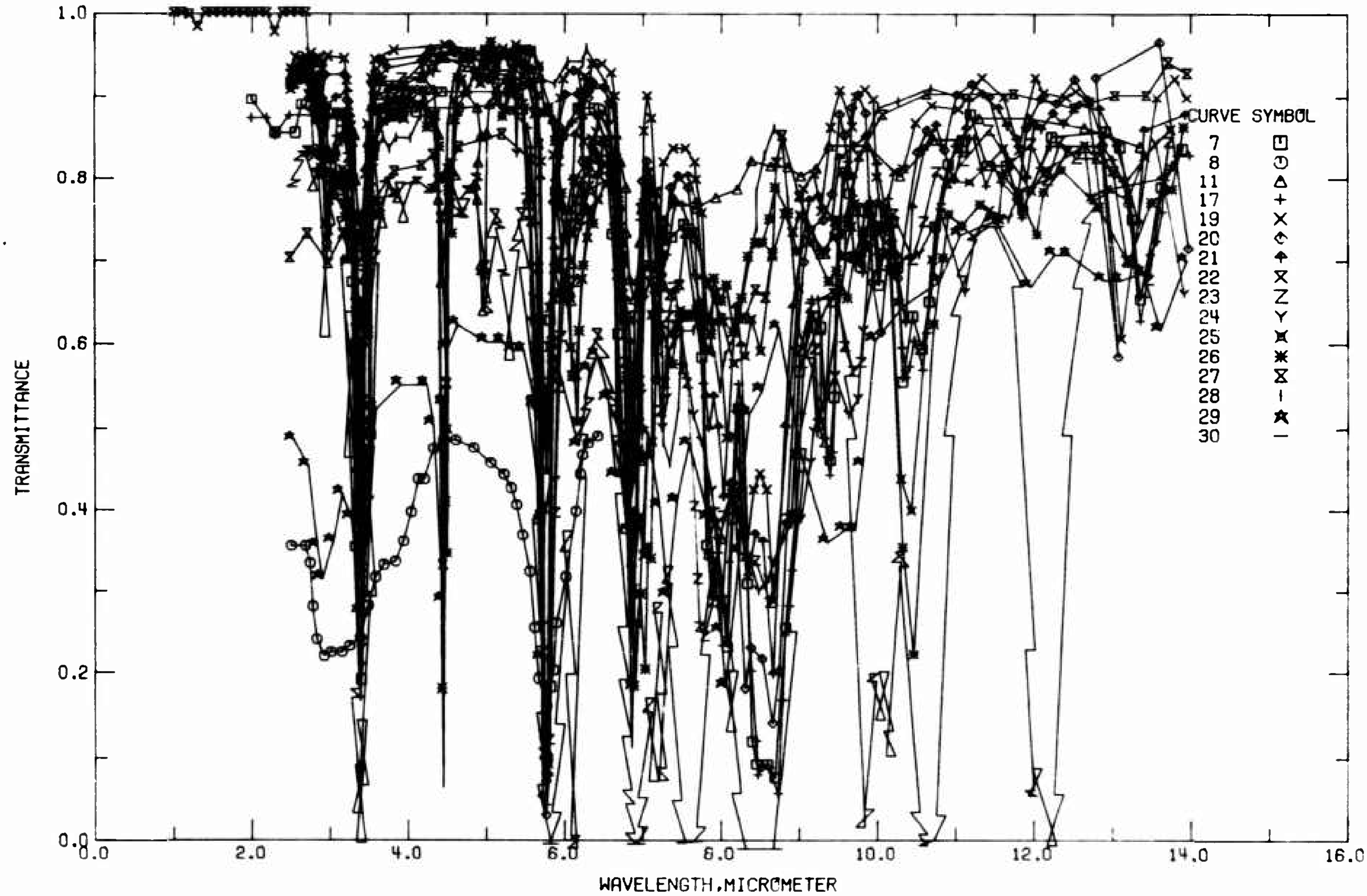


FIGURE 15-10. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC THIN FILMS (WAVELENGTH DEPENDENCE).

TABLE 15-11. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESINS (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T40338	Acitelli, M.A., Gumby, W.L., and Naujokas, A.A.	1966	0.2-2.2	298	Poly (Allyl-Methacrylate)	7.13 mm thickness; measurements were determined by Cary Spectrophotometer Model 14; the sample used was disc approx. 50 mm in diameter.
2	T40338	Acitelli, M.A., et al.	1966	0.2-2.2	298	Poly (Allyl-Methacrylate)	The above specimen; after 100 standard fade hours of solarization.
3	T40338	Acitelli, M.A., et al.	1966	0.2-2.2	298	Poly (isobutyl methacrylate)	6.67 mm thickness; measurements were determined by Cary Spectrophotometer Model 14; the sample used was disc approx. 50 mm in diameter.
4	T40338	Acitelli, M.A., et al.	1966	0.2-2.2	298	Poly (isobutyl methacrylate)	The above specimen; after 100 standard fade hours of solarization.
5	T40338	Acitelli, M.A., et al.	1966	0.2-2.2	298	Poly (ethylene glycol dimethacrylate)	6.95 mm thick disc approx. 50 mm in diameter; Cary Spectrophotometer Model 14 was employed.
6	T40338	Acitelli, M.A., et al.	1966	0.2-2.2	298	Poly (cyclohexyl methacrylate)	6.75 mm thick disc specimen approx. 50 mm in diameter; Cary Spectrophotometer was employed.
7	T19814	Moore, L.E., Prastein, M., Tompkins, E.H., and Van Ostenburg, D.O.	1958	2-15.0	293	Poly-n-butyl methacrylate	Refractive index 1.48 at λ = 5893 Å; unknown thickness.
8	T34840	Boyer-Kawenoki, F.	1966	2.5-6.5	293	Polyacrylic Acid	Specimen was obtained by making pellets with KBr and measured by Perkin-Elmer spectrometer; unfractioned polymer with molecular weight 25 000 determined by viscosymetric technique.
9	T47094	Holland, W.R.	1967	0.2-2.6	293	Acrylic Sheets	0.25 in. thick sheets; Perkin-Elmer Model 99 monochrometer was used.
10	T47094	Holland, W.R.	1967	0.2-2.6	293	Acrylic Sheets	Similar to the above specimen.
11	T48135	Hirai, T. and Nakada, O.	1968	2.5-16	~293	Polyacrylonitrile (PAN)	Thin film was formed on a rock salt crystal plate (30 mm diameter and 2 mm thick); infrared spectra was measured by using a Hitachi EP-2 infrared spectrometer; data were extracted from figure; θ ~0°.
12	T64206	Pennington, C.W. and Moore, G.L.	1971	0.4-2.6	~293	Acrylic Panel	Reflective type acrylic panel; transmittance spectra was obtained by using a DK-2 spectrometer; data were extracted from figure; θ ~0°.
13	T62587	Gilligan, J.E. and Brzuskiewicz, J.	1971	0.2-2.6	~293	DuPont Evacite 6011 (methyl-methacrylate)	0.015 in. thick sprayed film; Beckman DK-2 spectrometer was used; data were extracted from figure
14	T62587	Gilligan, J.E. and Brzuskiewicz, J.	1971	0.2-2.6	~293	DuPont Evacite 6011 (methyl-methacrylate)	Similar to the above specimen except 0.032 in. thick.
15	T62587	Gilligan, J.E. and Brzuskiewicz, J.	1971	0.2-2.6	~293	DuPont Evacite 6011 (methyl-methacrylate)	Similar to the above specimen except 0.054 in. thick.
16	T62587	Gilligan, J.E. and Brzuskiewicz, J.	1971	0.2-2.6	~293	DuPont Evacite 6011 (methyl-methacrylate)	0.035 in. thick film was obtained by a doctor blade technique; Beckman DK-2 spectrometer was used; data were extracted from figure.
17	T76812	Kagarise, R.E. and Weinberger, L.A.	1954	2-15	~293	Hypalon P-4	The specimen was obtained from DuPont Co.; dissolved in C_6H_6 and the resulting viscous solution was spread uniformly over a rock salt on KBr plate; the solvent was removed by heating in vacuum on normal evaporation at room temperature; a Perkin-Elmer Model 21 double beam spectrophotometer was used; data were extracted from figure.

TABLE 15-11. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESINS (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
18	T30490	Cobble, M.H., Fang, P.C., and Lumsdaine, E.	1966	0.3-1.6	~293	Methyl Methacrylate	The transmission spectra of the 2.5 in. slab of methyl methacrylate plastic is determined using a Beckman spectrometer; data were corrected for surface reflectance; data were extracted from figure; $\theta \sim 0°$.
19	T76795	Stimler, S.S. and Kagarise, R.E.	1966	2.5-25	~293	Zerlon-150 (Methyl methacrylate-styrene copolymer)	Film specimen was obtained from Dow Chemical; a Beckman IR-12 spectrophotometer was used to obtain spectra; data were extracted from figure; $\theta \sim 0°$.
20	T76795	Stimler, S.S. and Kagarise, R.E.	1966	2.5-25	~293	Bavick 11-X-1 (Methyl methacrylate-α-methylstyrene copolymer)	Film specimen was obtained from J. T. Baker Chemical Co.; other specifications similar to the above.
21	T76795	Stimler, S.S. and Kagarise, R.E.	1966	2.5-25	~293	Implax	Film specimen was obtained from Rohm and Haas Co.; other specifications similar to the above.
22	T68740	Janardhanan, K.K., Ramakrishnan, P.K., Rao, H.N.V., Subramanian, V., and Suryanarayana, C.V.	1972	1.0-2.8	~293	Perspex in methyl methacrylate	The transmission was studied by using a Carl Zeiss SPM-2 monochromator; $\theta \sim 0°$.
23	T76798	Lara, M.O.	1967	2.5-25	~293	Acrylic, Lacquer Brolite MIL-L-61352 (Andrew Brown Co.)	The specimen was condensed pyrolyzite on potassium bromide on sodium chloride; a Beckman IR-9 double beamed, prism-grating infrared spectrophotometer was used to obtain the spectra; data were extracted from figure; $\theta \sim 0°$.
24	T76798	Lara, M.O.	1967	2.5-25	~293	Acrylic LATEX Spred House Paint (The Glidden Co.)	Similar to the above specimen.
25	T76798	Lara, M.O.	1967	2.5-25	~293	Orlon (Polyacrylonitrile)	Similar to the above specimen.
26	T76798	Lara, M.O.	1967	2.5-25	~293	Orlon (Polyacrylonitrile)	Similar to the above specimen.
27	T77043	Baetoniu, P.	1969	2.5-15	~293	Orlon 42	No details given; data were extracted from figure; $\theta \sim 0°$.
28	T77043	Baetoniu, P.	1969	2.5-15	~293	(Polyacrylonitrile)	Similar to the above specimen.
29	T77043	Baetoniu, P.	1969	2.5-15	~293	Creslan	Similar to the above specimen.
30	E26638	Carbajal, B.G. III	1966	2.5-25	~293	MMA	Methylmethacrylate; data were extracted from the figure; $\theta \sim 0°$.

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ
CURVE 1	
T = 293.	
0.394	0.200
0.400	0.207
0.470	0.207
0.490	0.211
0.515	0.211
0.537	0.208
0.570	0.209
0.627	0.217
0.665	0.223
0.745	0.236
0.786	0.253
0.780	0.262
0.804	0.270
0.830	0.269
0.873	0.281
0.914	0.281
0.949	0.290
0.986	0.295
1.021	0.338
1.043	0.293
1.059	0.246
1.059	0.194
1.079	0.161
1.109	0.153
1.127	0.169
1.148	0.225
1.167	0.263
1.189	0.303
1.205	0.312
1.225	0.318
1.250	0.318
1.268	0.303
1.283	0.260
1.365	0.164
1.410	0.132
1.446	0.117
1.436	0.140
1.521	0.188
1.542	0.264
CURVE 1 (CONT.)	
1.567	0.292
1.596	0.308
1.641	0.300
1.648	0.264
1.675	0.238
1.702	0.122
1.738	0.069
1.765	0.041
1.795	0.032
1.820	0.045
1.845	0.079
1.871	0.100
1.901	0.117
1.928	0.109
1.941	0.000
1.991	0.100
1.991	0.135
2.051	0.145
2.075	0.123
2.143	0.039
2.188	0.020
0.200	0.000
0.292	0.000
0.304	0.014
0.316	0.044
0.326	0.084
0.336	0.149
0.346	0.243
0.346	0.644
0.350	0.726
0.367	0.807
0.377	0.832
0.390	0.854
0.403	0.874
0.418	0.884
0.444	0.894
0.539	0.901
0.549	0.894
0.558	0.901
0.617	0.901
CURVE 1 (CONT.)	
0.695	0.912
0.803	0.928
0.842	0.928
0.857	0.917
0.869	0.899
0.887	0.899
0.901	0.891
0.919	0.901
0.936	0.911
0.963	0.915
1.004	0.895
1.036	0.895
1.058	0.907
1.080	0.907
1.091	0.883
1.100	0.886
1.110	0.795
1.118	0.818
1.136	0.603
1.140	0.594
1.148	0.594
1.153	0.632
1.159	0.646
1.171	0.598
1.176	0.590
1.186	0.614
1.197	0.674
1.214	0.795
1.223	0.840
1.236	0.866
1.255	0.875
1.263	0.892
1.267	0.869
1.274	0.869
1.279	0.849
1.284	0.857
1.288	0.877
1.304	0.877
1.311	0.865
1.325	0.784
CURVE 1 (CONT.)	
1.329	0.797
1.352	0.610
1.361	0.602
1.366	0.545
1.374	0.524
1.387	0.544
1.398	0.528
1.405	0.569
1.416	0.553
1.426	0.583
1.435	0.583
1.453	0.660
1.467	0.712
1.486	0.764
1.509	0.793
1.524	0.808
1.540	0.808
1.559	0.784
1.568	0.745
1.577	0.751
1.594	0.705
1.601	0.652
1.621	0.069
1.626	0.045
1.629	0.065
1.640	0.270
1.648	0.300
1.665	0.040
1.674	0.015
1.699	0.008
1.712	0.051
1.720	0.051
1.728	0.041
1.744	0.049
1.755	0.116
1.771	0.170
1.790	0.220
1.807	0.245
1.831	0.292
1.846	0.332
CURVE 1 (CONT.)	
1.870	0.332
1.881	0.303
1.894	0.197
1.902	0.185
1.913	0.214
1.919	0.257
1.925	0.267
1.932	0.257
1.944	0.212
1.954	0.217
1.963	0.267
1.972	0.288
1.978	0.302
1.988	0.289
1.995	0.237
2.001	0.211
2.014	0.223
2.022	0.204
2.032	0.191
2.047	0.219
2.056	0.219
2.069	0.172
2.081	0.151
2.098	0.000
2.114	0.000
2.124	0.019
2.140	0.015
2.150	0.022
2.165	0.017
2.180	0.043
2.200	0.042
CURVE 2	
T = 296.	
0.230	0.000
0.291	0.000
0.302	0.017
0.322	0.249
0.356	0.649
CURVE 2 (CONT.)	
0.366	0.721
0.378	0.770
0.387	0.593
0.396	0.827
0.410	0.842
0.435	0.853
0.474	0.855
0.534	[illegible]
0.541	0.870
0.557	0.888
0.649	0.895
0.745	0.906
0.797	0.915
0.841	0.915
0.857	0.911
0.865	0.889
0.880	0.891
0.895	0.881
0.909	0.881
0.926	0.898
0.959	0.901
0.965	0.894
0.979	0.894
0.998	0.883
1.016	0.883
1.059	0.897
1.075	0.897
1.080	0.894
1.085	0.876
1.096	0.876
1.107	0.835
1.114	0.817
1.124	0.722
1.133	0.635
1.147	0.595
1.155	0.642
1.163	0.608
1.170	0.583
1.184	0.603
1.203	0.735

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE	2(CONT.)	CURVE	2(CONT.)	CURVE	2(CONT.)	CURVE	3(CONT.)	CURVE	3(CONT.)	CURVE	3(CONT.)
1.210	0.793	1.644	0.245	2.096	0.000	0.932	0.884	1.602	0.737	2.140	0.055
1.220	0.831	1.650	0.223	2.110	0.000	0.951	0.888	1.611	0.707	2.151	0.075
1.229	0.853	1.661	0.043	2.122	0.021	0.962	0.869	1.624	0.640	2.158	0.061
1.252	0.853	1.670	0.021	2.137	0.013	0.970	0.886	1.641	0.620	2.173	0.091
1.259	0.384	1.680	0.017	2.148	0.021	1.009	0.857	1.664	0.185	2.200	0.064
1.262	0.362	1.689	0.012	2.158	0.015	1.052	0.870	1.672	0.109		
1.269	0.355	1.697	0.022	2.167	0.029	1.082	0.883	1.678	0.036	CURVE 4	
1.277	0.843	1.705	0.050	2.173	0.039	1.136	0.883	1.686	0.011	T = 296.	
1.285	0.868	1.714	0.050	2.192	0.041	1.121	0.850	1.701	0.011		
1.299	0.368	1.726	0.042			1.138	0.755	1.711	0.026	0.200	0.004
1.303	0.858	1.738	0.053	CURVE 3		1.144	0.671	1.722	0.026	0.229	0.021
1.313	0.805	1.756	0.135	T = 296.		1.155	0.650	1.729	0.021	0.253	0.044
1.319	0.773	1.772	0.183			1.183	0.376	1.748	0.059	0.274	0.080
1.326	0.793	1.787	0.215	0.282	0.000	1.209	0.681	1.763	0.054	0.290	0.110
1.347	0.608	1.807	0.250	0.295	0.009	1.218	0.727	1.774	0.162	0.299	0.178
1.356	0.599	1.826	0.292	0.295	0.279	1.223	0.787	1.781	0.183	0.309	0.299
1.362	0.536	1.835	0.314	0.307	0.497	1.241	0.829	1.796	0.169	0.329	0.412
1.368	0.521	1.648	0.324	0.321	0.643	1.258	0.548	1.828	0.233	0.345	0.482
1.379	0.538	1.858	0.324	0.332	0.722	1.266	0.843	1.837	0.309	0.361	0.634
1.390	0.532	1.871	0.313	0.347	0.766	1.269	0.870	1.855	0.343	0.369	0.693
1.401	0.555	1.889	0.211	0.365	0.798	1.282	0.863	1.882	0.314	0.384	0.757
1.409	0.546	1.897	0.198	0.384	0.826	1.299	0.862	1.894	0.260	0.402	0.789
1.416	0.570	1.905	0.216	0.406	0.846	1.320	0.851	1.903	0.247	0.427	0.822
1.427	0.583	1.914	0.247	0.429	0.861	1.341	0.749	1.914	0.259	0.455	0.836
1.448	0.658	1.918	0.256	0.457	0.873	1.352	0.574	1.922	0.291	0.509	0.855
1.456	0.693	1.925	0.243	0.491	0.886	1.358	0.435	1.930	0.300	0.588	0.872
1.471	0.731	1.934	0.219	0.542	0.896	1.375	0.450	1.936	0.288	0.660	0.881
1.485	0.765	1.943	0.206	0.573	0.904	1.337	0.440	1.942	0.243	0.721	0.881
1.511	0.792	1.946	0.222	0.658	0.904	1.397	0.506	1.949	0.230	0.730	0.877
1.535	0.792	1.951	0.279	0.677	0.912	1.050	0.496	1.956	0.253	0.751	0.877
1.550	0.780	1.968	0.294	0.716	0.913	1.409	0.555	1.961	0.276	0.770	0.871
1.560	0.739	1.978	0.294	0.727	0.905	1.415	0.572	1.971	0.292	0.782	0.876
1.568	0.748	1.998	0.223	0.749	0.905	1.425	0.563	1.985	0.292	0.804	0.876
1.583	0.714	2.011	0.223	0.756	0.912	1.436	0.603	2.013	0.344	0.815	0.871
1.595	0.652	2.028	0.199	0.768	0.902	1.454	0.658	2.028	0.363	0.829	0.875
1.602	0.558	2.043	0.219	0.783	0.906	1.469	0.697	2.045	0.319	0.847	0.875
1.618	0.101	2.054	0.211	0.828	0.906	1.490	0.713	2.068	0.252	0.868	0.856
1.622	0.053	2.065	0.176	0.854	0.899	1.510	0.783	2.086	0.226	0.886	0.847
1.633	0.303	2.075	0.155	0.878	0.885	1.519	0.802	2.106	0.101	0.895	0.835
1.640	0.322	2.089	0.056	0.905	0.835	1.534	0.811	2.127	0.044	0.905	0.816

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE	4(CONT.)	CURVE	4(CONT.)	CURVE 5		CURVE	5(CONT.)	CURVE	5(CONT.)	CURVE	6(CONT.)
0.923	0.854	1.527	0.789	T = 296.		1.369	0.497	2.200	0.059	1.209	0.708
0.348	0.864	1.538	0.789	0.200	0.000	1.388	0.445			1.216	0.754
0.959	0.347	1.552	0.776	0.300	0.000	1.394	0.445	CURVE 6		1.228	0.812
0.976	0.360	1.572	0.745	0.317	0.011	1.425	0.393	T = 296.		1.243	0.859
0.991	0.345	1.599	0.712	0.329	0.362	1.451	0.497			1.260	0.891
1.015	0.834	1.617	0.609	0.363	0.449	1.470	0.538	0.300	0.000	1.282	0.903
1.026	0.845	1.644	0.597	0.381	0.590	1.528	0.692	0.321	0.307	1.309	0.903
1.056	0.847	1.667	0.156	0.412	0.723	1.577	0.687	0.335	0.476	1.324	0.873
1.071	0.858	1.683	0.022	0.432	0.775	1.598	0.677	0.350	0.567	1.347	0.736
1.098	0.859	1.696	0.014	0.471	0.819	1.610	0.664	0.366	0.659	1.358	0.616
1.114	0.846	1.708	0.029	0.498	0.837	1.620	0.613	0.386	0.720	1.370	0.488
1.125	0.807	1.722	0.029	0.553	0.850	1.631	0.623	0.417	0.774	1.380	0.563
1.144	0.652	1.731	0.024	0.822	0.857	1.643	0.588	0.446	0.812	1.394	0.510
1.154	0.515	1.750	0.059	0.861	0.852	1.647	0.527	0.473	0.840	1.404	0.562
1.164	0.504	1.759	0.059	0.882	0.843	1.658	0.476	0.512	0.869	1.429	0.625
1.175	0.465	1.771	0.119	0.906	0.813	1.673	0.088	0.560	0.882	1.443	0.703
1.180	0.363	1.780	0.179	0.939	0.815	1.680	0.073	0.660	0.901	1.470	0.748
1.192	0.465	1.798	0.169	0.954	0.827	1.694	0.073	0.715	0.913	1.475	0.775
1.205	0.653	1.823	0.248	0.962	0.818	1.696	0.042	0.766	0.919	1.490	0.781
1.222	0.770	1.837	0.319	0.972	0.829	1.723	0.014	0.840	0.919	1.512	0.826
1.253	0.323	1.850	0.341	1.018	0.806	1.744	0.035	0.869	0.939	1.536	0.349
1.261	0.337	1.876	0.329	1.051	0.806	1.768	0.075	0.883	0.889	1.555	0.317
1.266	0.347	1.888	0.292	1.094	0.818	1.798	0.085	0.909	0.848	1.595	0.794
1.286	0.835	1.899	0.258	1.105	0.818	1.855	0.205	0.929	0.898	1.610	0.700
1.313	0.833	1.905	0.258	1.120	0.798	1.868	0.221	0.944	0.912	1.618	0.758
1.325	0.604	1.922	0.296	1.134	0.742	1.885	0.188	0.957	0.898	1.637	0.695
1.347	0.667	1.947	0.235	1.146	0.695	1.902	0.032	0.964	0.915	1.648	0.464
1.352	0.537	1.967	0.290	1.173	0.500	1.911	0.060	0.988	0.931	1.662	0.246
1.359	0.450	1.983	0.250	1.184	0.490	1.931	0.125	1.011	0.892	1.681	0.054
1.366	0.433	2.015	0.337	1.200	0.524	1.949	0.120	1.038	0.892	1.689	0.019
1.375	0.448	2.026	0.352	1.222	0.535	1.980	0.213	1.059	0.909	1.698	0.013
1.384	0.430	2.033	0.337	1.233	0.625	1.994	0.225	1.075	0.915	1.712	0.013
1.390	0.480	2.067	0.249	1.248	0.713	2.012	0.225	1.098	0.915	1.723	0.022
1.394	0.494	2.083	0.226	1.258	0.751	2.050	0.180	1.110	0.895	1.735	0.014
1.401	0.485	2.100	0.130	1.280	0.790	2.077	0.185	1.124	0.855	1.749	0.024
1.414	0.553	2.130	0.046	1.289	0.800	2.093	0.159	1.156	0.593	1.762	0.070
1.422	0.539	2.151	0.073	1.306	0.809	2.111	0.069	1.169	0.424	1.768	0.077
1.467	0.536	2.163	0.037	1.321	0.791	2.139	0.036	1.186	0.346	1.781	0.066
1.464	0.691	2.175	0.091	1.335	0.740	2.162	0.070	1.192	0.409	1.793	0.091
1.510	0.770	2.200	0.073	1.366	0.534	2.186	0.073	1.209	0.578	1.815	0.132

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (AVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ
CURVE	6 (CONT.)
1.823	0.204
1.834	0.235
1.845	0.259
1.861	0.259
1.885	0.221
1.902	0.234
1.922	0.234
1.949	0.236
1.992	0.296
1.996	0.318
2.013	0.326
2.029	0.290
2.045	0.302
2.083	0.250
2.095	0.171
2.119	0.105
2.131	0.055
2.163	0.132
2.185	0.150
2.200	0.137
CURVE 7	
T = 293.	
2.00	0.895
2.30	0.855
2.55	0.855
2.64	0.859
2.92	0.864
3.05	0.878
3.14	0.878
3.23	0.863
3.29	0.799
3.29	0.673
3.32	0.353
3.40	0.192
3.45	0.407
3.52	0.491
3.53	0.837
3.78	0.879

λ	τ
CURVE	7 (CONT.)
4.11	0.879
4.43	0.905
5.30	0.905
5.47	0.882
5.56	0.767
5.67	0.388
5.77	0.099
5.82	0.184
5.82	0.627
5.90	0.782
5.98	0.852
6.19	0.884
6.39	0.834
6.54	0.845
6.62	0.731
6.69	0.611
6.79	0.376
6.87	0.449
6.90	0.632
7.02	0.760
7.20	0.606
7.22	0.667
7.37	0.727
7.53	0.743
7.76	0.583
7.82	0.355
8.03	0.288
8.08	0.231
8.16	0.401
8.23	0.523
8.28	0.369
8.34	0.309
8.40	0.120
8.45	0.093
8.59	0.093
8.69	0.076
8.83	0.255
8.96	0.394
8.96	0.467
9.01	0.566

λ	τ
CURVE	7 (CONT.)
9.19	0.632
9.28	0.619
9.28	0.517
9.40	0.459
9.45	0.536
9.50	0.732
9.60	0.808
9.65	0.780
9.71	0.703
9.79	0.691
9.84	0.759
9.93	0.759
10.03	0.669
10.12	0.747
10.20	0.747
10.27	0.690
10.33	0.553
10.46	0.632
10.58	0.593
10.67	0.649
10.75	0.740
10.91	0.818
11.10	0.846
11.20	0.877
11.41	0.816
11.66	0.816
11.87	0.760
12.24	0.850
12.93	0.856
13.11	0.838
13.27	0.749
13.37	0.652
13.64	0.788
13.91	0.836
14.16	0.812
14.50	0.812
14.63	0.819
14.79	0.802
15.00	0.824

λ	τ
CURVE 8	
T = 293.	
2.50	0.354
2.68	0.354
2.74	0.333
2.78	0.281
2.83	0.240
2.92	0.219
3.01	0.224
3.15	0.224
3.25	0.232
3.39	0.242
3.49	0.282
3.58	0.316
3.69	0.331
3.84	0.335
3.94	0.360
4.04	0.397
4.13	0.435
4.21	0.436
4.33	0.474
4.46	0.485
[illegible]	0.485
4.84	0.475
5.06	0.456
5.23	0.442
5.32	0.426
5.39	0.406
5.47	0.366
5.56	0.323
5.62	0.255
5.67	0.193
5.77	0.162
5.86	0.203
5.90	0.261
6.02	0.317
6.15	0.398
6.21	0.442
6.24	0.466
6.31	0.481
6.43	0.490

λ	τ
CURVE 9	
T = 293.	
0.417	0.824
0.429	0.813
0.446	0.808
0.475	0.805
0.487	0.812
0.499	0.828
0.513	0.834
0.619	0.834
0.635	0.839
0.645	0.846
0.661	0.862
0.675	0.875
0.694	0.901
0.710	0.916
0.724	0.923
0.754	0.923
0.774	0.917
0.807	0.907
0.841	0.897
0.878	0.889
0.912	0.883
0.941	0.833
0.980	0.887
1.034	0.894
1.070	0.897
1.105	0.897
1.133	0.894
1.169	0.888
1.195	0.881
1.219	0.873
1.242	0.861
1.262	0.844
1.286	0.816
1.322	0.751
1.349	0.709
1.361	0.665
1.406	0.644
1.430	0.629
1.463	0.616

λ	τ
CURVE	9 (CONT.)
1.498	0.611
1.541	0.607
1.589	0.603
1.622	0.595
1.642	0.588
1.704	0.533
1.737	0.499
1.759	0.480
1.786	0.462
1.815	0.449
1.835	0.449
1.851	0.491
1.865	0.473
1.879	0.490
1.892	0.507
1.905	0.532
1.920	0.567
1.943	0.630
1.954	0.679
1.962	0.708
1.970	0.733
1.985	0.758
2.000	0.775
2.014	0.788
2.029	0.795
2.051	0.804
2.086	0.809
2.153	0.815
2.305	0.822
2.510	0.829
CURVE 10	
T = 293.	
0.412	0.830
0.429	0.840
0.455	0.856
0.471	0.870
0.482	0.882
0.498	0.891

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 10(CONT.)	
0.516	0.898
0.554	0.898
0.566	0.901
0.593	0.913
0.614	0.917
0.629	0.917
0.645	0.912
0.672	0.900
0.696	0.881
0.707	0.879
0.726	0.879
0.737	0.883
0.748	0.889
0.757	0.909
0.765	0.921
0.775	0.931
0.783	0.937
0.796	0.942
0.807	0.945
0.833	0.945
0.851	0.940
0.870	0.931
0.864	0.922
0.905	0.907
0.922	0.900
0.942	0.893
0.969	0.885
0.997	0.880
1.030	0.875
1.087	0.869
1.191	0.869
1.212	0.864
1.232	0.859
1.245	0.851
1.254	0.839
1.274	0.706
1.290	0.713
1.311	0.670
1.333	0.638
1.345	0.618

λ	τ
CURVE 10(CONT.)	
1.350	0.606
1.385	0.590
1.404	0.582
1.422	0.577
1.446	0.570
1.476	0.565
1.511	0.562
1.573	0.549
1.595	0.541
1.614	0.533
1.645	0.521
1.682	0.502
1.722	0.478
1.758	0.456
1.783	0.440
1.816	0.408
1.841	0.383
1.867	0.352
1.901	0.299
1.932	0.233
1.969	0.146
1.986	0.109
1.996	0.092
2.010	0.077
2.023	0.066
2.043	0.060
2.066	0.054
2.097	0.049
2.130	0.043
2.172	0.037
2.245	0.031
2.322	0.027
2.500	0.028
CURVE 11	
T = 293.	
2.50	0.926
2.74	0.924
2.76	0.902

λ	τ
CURVE 11(CONT.)	
2.88	0.903
2.95	0.876
2.98	0.834
3.07	0.834
3.11	0.878
3.22	0.879
3.32	0.853
3.33	0.796
3.38	0.751
3.42	0.698
3.42	0.755
3.47	0.815
3.54	0.886
3.62	0.901
3.82	0.909
3.94	0.914
4.18	0.926
4.33	0.908
4.40	0.853
4.40	0.772
4.43	0.8[illegible]2
4.52	0.762
4.53	0.807
4.64	0.880
4.74	0.905
4.90	0.884
4.94	0.851
4.90	0.819
4.88	0.790
4.90	0.772
4.94	0.693
4.96	0.638
5.00	0.682
5.02	0.854
5.05	0.889
5.14	0.907
5.27	0.923
5.71	0.923
5.87	0.671
5.94	0.831

λ	τ
CURVE 11(CONT.)	
5.95	0.769
6.01	0.730
6.11	0.695
6.25	0.760
6.34	0.785
6.60	0.799
6.65	0.819
6.72	0.820
6.80	0.787
6.80	0.733
6.84	0.676
6.90	0.652
6.94	0.675
6.97	0.721
7.05	0.752
7.17	0.766
7.28	0.747
7.42	0.773
7.69	0.762
7.94	0.775
8.22	0.785
8.40	0.822
8.64	0.815
8.87	0.814
9.03	0.802
9.23	0.812
9.39	0.840
9.88	0.840
10.3[illegible]	0.802
10.73	0.847
11.05	0.847
11.31	0.872
11.95	0.872
12.66	0.851
13.37	0.839
14.41	0.846
15.60	0.821

λ	τ
CURVE 12	
T = 293.	
0.394	0.200
0.400	0.207
0.470	0.207
0.490	0.211
0.515	0.211
0.537	0.208
0.570	0.239
0.627	0.217
0.665	0.223
0.745	0.236
0.766	0.253
0.780	0.262
0.804	0.270
0.830	0.269
0.873	0.281
0.914	0.281
0.949	0.290
0.986	0.295
1.043	0.293
1.059	0.246
1.059	0.194
1.079	0.161
1.109	0.153
1.127	0.169
1.148	0.225
1.170	0.283
1.199	0.303
1.205	0.312
1.225	0.313
1.250	0.316
1.268	0.303
1.283	0.260
1.365	0.164
1.410	0.132
1.446	0.117
1.486	0.140
1.521	0.188
1.542	0.264
1.567	0.292

λ	τ
CURVE 12(CONT.)	
1.596	0.308
1.641	0.330
1.648	0.264
1.675	0.236
1.702	0.122
1.738	0.069
1.756	0.041
1.795	0.032
1.820	0.045
1.845	0.079
1.871	0.100
1.901	0.117
1.928	0.109
1.941	0.0[illegible]
1.991	0.100
1.991	0.135
2.051	0.145
2.075	0.123
2.143	0.039
2.188	0.020
2.275	0.000
CURVE 13	
T = 293.	
0.213	0.063
0.231	0.158
0.264	0.283
0.289	0.365
0.306	0.415
0.317	0.427
0.472	0.481
0.668	0.540
0.706	0.509
1.116	0.575
1.562	0.646
1.958	0.709
2.011	0.714
2.077	0.714
2.148	0.710

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 13 (CONT.)		CURVE 14 (CONT.)		CURVE 15 (CONT.)		CURVE 16 (CONT.)		CURVE 17 (CONT.)		CURVE 17 (CONT.)	
2.184	0.705	2.294	0.481	2.393	0.660	2.035	0.732	5.18	0.898	7.78	0.552
2.197	0.693	2.309	0.512	2.415	0.653	2.104	0.741	5.35	0.881	7.84	0.346
2.237	0.591	2.327	0.542	2.511	0.706	2.180	0.741	5.54	0.860	7.88	0.294
2.262	0.524	2.339	0.580	2.600	0.756	2.234	0.735	5.58	0.838	7.92	0.333
2.275	0.511	2.353	0.588			2.254	0.725	5.61	0.778	7.97	0.346
2.287	0.522	2.375	0.581	CURVE 16		2.260	0.686	5.65	0.744	8.02	0.233
2.308	0.567	2.415	0.557	T = 293.		2.281	0.486	5.68	0.595	8.08	0.243
2.325	0.503	2.446	0.584			2.299	0.482	5.74	0.124	8.11	0.335
2.340	0.538	2.533	0.647	0.186	0.056	2.325	0.541	5.77	0.042	8.14	0.383
2.351	0.547	2.600	0.700	0.208	0.126	2.338	0.579	5.80	0.079	8.20	0.520
2.363	0.637			0.229	0.198	2.357	0.591	5.84	0.557	8.23	0.551
2.401	0.612	CURVE 15		0.255	0.240	2.394	0.570	5.85	0.726	8.27	0.518
2.413	0.605	T = 293.		0.287	0.278	2.418	0.555	5.91	0.760	8.33	0.339
2.434	0.613			0.309	0.305	2.509	0.635	5.95	0.816	8.39	0.202
2.487	0.657	0.210	0.070	0.340	0.324	2.573	0.697	6.01	0.852	8.45	0.121
2.554	0.711	0.228	0.253	0.330	0.347	2.600	0.720	6.11	0.867	8.47	0.030
2.600	0.749	0.232	0.383	0.426	0.369			6.24	0.876	8.53	0.089
		0.261	0.531	0.490	0.395	CURVE 17		6.47	0.876	8.61	0.039
CURVE 14		0.284	0.649	0.559	0.420	T = 293.		6.60	0.851	8.73	0.057
T = 293.		0.306	0.734	0.648	0.446			6.65	0.324	8.79	0.169
		0.322	0.785	0.772	0.486	2.00	0.872	6.72	0.448	8.82	0.246
0.242	0.055	0.336	0.801	0.888	0.525	2.20	0.872	6.80	0.378	8.88	0.282
0.263	0.174	0.359	0.811	1.011	0.566	2.30	0.852	6.89	0.438	8.92	0.325
0.290	0.230	0.449	0.815	1.060	0.580	2.49	0.875	6.91	0.544	9.00	0.445
0.308	0.373	0.669	0.823	1.112	0.600	2.79	0.875	6.96	0.643	9.03	0.518
0.316	0.380	1.010	0.830	1.169	0.617	2.92	0.852	6.98	0.748	9.06	0.571
0.339	0.399	1.198	0.831	1.225	0.635	2.98	0.873	7.02	0.773	9.11	0.614
0.492	0.452	1.508	0.831	1.300	0.655	3.23	0.869	7.07	0.749	9.17	0.652
0.587	0.509	1.774	0.829	1.365	0.671	3.27	0.846	7.11	0.679	9.25	0.652
0.706	0.504	1.962	0.829	1.436	0.682	3.29	0.802	7.16	0.638	9.29	0.611
1.111	0.565	2.012	0.823	1.474	0.689	3.39	0.172	7.20	0.587	9.32	0.551
1.539	0.630	2.064	0.802	1.524	0.689	3.41	0.210	7.23	0.625	9.36	0.464
1.969	0.695	2.164	0.776	1.592	0.669	3.44	0.401	7.25	0.684	9.40	0.441
2.015	0.696	2.179	0.766	1.654	0.648	3.49	0.444	7.28	0.736	9.44	0.470
2.055	0.695	2.245	0.645	1.703	0.624	3.53	0.791	7.32	0.706	9.50	0.533
2.102	0.689	2.272	0.603	1.728	0.624	3.55	0.830	7.42	0.766	9.57	0.803
2.134	0.668	2.300	0.621	1.820	0.661	3.62	0.857	7.52	0.766	9.63	0.821
2.193	0.649	2.332	0.653	1.862	0.680	3.75	0.872	7.59	0.743	9.70	0.801
2.262	0.437	2.339	0.664	1.931	0.702	3.96	0.884	7.67	0.682	9.73	0.778
2.277	0.472	2.353	0.675	1.979	0.719	4.71	0.884	7.74	0.648	9.76	0.754

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 17(CONT.)		CURVE 17(CONT.)		CURVE 18(CONT.)		CURVE 19(CONT.)		CURVE 19(CONT.)		CURVE 19(CONT.)	
9.80	0.705	13.43	0.656	0.91	0.924	2.84	0.947	6.18	0.932	9.29	0.759
9.82	0.685	13.50	0.707	0.92	0.982	2.87	0.947	6.23	0.905	9.42	0.861
9.85	0.711	13.58	0.723	0.93	0.941	2.91	0.934	6.26	0.845	9.53	0.958
9.90	0.752	13.65	0.758	0.95	0.829	2.98	0.950	6.28	0.926	9.69	0.862
9.92	0.771	13.69	0.798	0.97	0.706	3.20	0.947	6.33	0.917	9.74	0.899
9.98	0.746	13.77	0.817	1.01	0.785	3.22	0.920	6.37	0.941	9.85	0.909
10.02	0.707	13.85	0.829	1.04	0.940	3.24	0.887	6.49	0.941	9.96	0.896
10.05	0.688	14.00	0.829	1.06	0.763	3.27	0.848	6.61	0.930	10.00	0.801
10.08	0.713	14.13	0.831	1.09	0.251	3.28	0.863	6.66	0.900	10.08	0.735
10.13	0.754	14.24	0.786	1.10	0.032	3.31	0.718	6.68	0.682	10.22	0.803
10.15	0.774	14.35	0.802	1.13	0.000	3.32	0.747	6.72	0.739	10.34	0.512
10.21	0.740	14.39	0.812	1.15	0.136	3.34	0.627	6.76	0.658	10.50	0.365
10.33	0.595	14.48	0.812	1.16	0.298	3.36	0.722	6.84	0.627	10.71	0.838
10.38	0.559	14.66	0.798	1.18	0.456	3.39	0.460	6.86	0.485	11.05	0.883
10.42	0.572	15.00	0.798	1.19	0.654	3.47	0.804	6.93	0.571	11.35	0.924
10.48	0.603			1.20	0.745	3.49	0.865	6.96	0.555	11.63	0.699
10.55	0.588	CURVE 18		1.21	0.768	3.52	0.838	7.03	0.357	11.82	0.835
10.59	0.568	T = 293.		1.23	0.783	3.54	0.923	7.07	0.961	12.03	0.924
10.64	0.612			1.26	0.756	3.58	0.945	7.13	0.872	12.14	0.905
10.83	0.768	0.32	0.000	1.27	0.491	3.83	0.956	7.17	0.783	12.42	0.899
10.92	0.812	0.32	0.455	1.29	0.217	4.48	0.962	7.20	0.693	12.55	0.907
11.01	0.840	0.34	0.500	1.30	0.000	5.00	0.953	7.28	0.820	12.72	0.894
11.08	0.833	0.34	0.716	1.41	0.000	5.11	0.946	7.40	0.837	12.89	0.847
11.15	0.833	0.36	0.799	1.42	0.134	5.23	0.958	7.56	0.837	13.12	0.606
11.19	0.849	0.38	0.885	1.45	0.286	5.36	0.950	7.67	0.320	13.59	0.898
11.25	0.849	0.43	0.929	1.47	0.354	5.40	0.962	7.69	0.798	13.81	0.923
11.34	0.812	0.50	0.955	1.49	0.386	5.56	0.933	7.77	0.757	13.97	0.898
11.40	0.790	0.57	0.971	1.51	0.339	5.62	0.933	7.83	0.625	14.20	0.454
11.50	0.816	0.62	0.979	1.53	0.209	5.67	0.901	7.95	0.661	14.47	0.900
11.59	0.795	0.68	0.979	1.55	0.130	5.71	0.821	8.08	0.488	14.65	0.921
11.80	0.775	0.70	0.969	1.58	0.000	5.73	0.401	8.18	0.490	14.97	0.912
11.86	0.751	0.72	0.954			5.75	0.104	8.25	0.429	15.38	0.925
11.96	0.783	0.73	0.957	CURVE 19		5.77	0.076	8.32	0.341	16.05	0.925
12.09	0.814	0.74	0.986	T = 293.		5.79	0.093	8.42	0.424	16.84	0.914
12.22	0.840	0.75	0.981			5.85	0.602	8.50	0.443	17.54	0.894
12.89	0.840	0.80	0.981	2.50	0.947	5.87	0.829	8.59	0.424	18.28	0.673
13.01	0.824	0.81	0.858	2.72	0.946	5.93	0.846	8.67	0.288	20.37	0.869
13.15	0.796	0.83	0.794	2.75	0.940	5.96	0.897	9.00	0.666	20.79	0.851
13.22	0.765	0.87	0.617	2.78	0.945	6.00	0.922	9.07	0.786	21.41	0.856
13.37	0.627	0.89	0.820	2.82	0.941	6.08	0.932	9.20	0.805	22.42	0.856

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ
CURVE 19(CONT.)	
23.58	0.835
24.21	0.811
25.00	0.776
CURVE 20	
T = 293.	
2.50	0.915
2.66	0.922
2.69	0.927
2.75	0.904
2.78	0.913
2.82	0.913
2.84	0.924
2.87	0.924
2.90	0.896
2.94	0.927
3.19	0.927
3.22	0.894
3.24	0.860
3.25	0.874
3.27	0.807
3.29	0.792
3.32	0.593
3.34	0.446
3.36	0.581
3.40	0.323
3.43	0.598
3.49	0.839
3.52	0.809
3.54	0.915
3.59	0.933
3.69	0.944
4.00	0.954
4.23	0.948
4.38	0.956
4.57	0.960
4.98	0.942
5.10	0.927
5.21	0.951

λ	τ
CURVE 20(CONT.)	
5.37	0.951
5.55	0.915
5.63	0.683
5.70	0.394
5.72	0.053
5.77	0.029
5.84	0.595
5.88	0.769
5.95	0.862
6.02	0.902
6.18	0.902
6.21	0.886
6.24	0.823
6.27	0.907
6.32	0.897
6.37	0.918
6.52	0.911
6.58	0.891
6.60	0.793
6.64	0.784
6.69	0.515
6.72	0.481
6.80	0.472
6.83	0.394
6.86	0.329
6.90	0.397
6.94	0.387
7.01	0.795
7.06	0.821
7.11	0.796
7.12	0.694
7.18	0.556
7.23	0.709
7.30	0.723
7.37	0.787
7.47	0.801
7.59	0.787
7.68	0.724
7.86	0.396
7.93	0.386

λ	τ
CURVE 20(CONT.)	
8.01	0.280
8.13	0.431
8.18	0.412
8.31	0.182
8.39	0.230
8.53	0.216
8.67	0.142
8.75	0.201
8.98	0.594
9.07	0.697
9.14	0.737
9.32	0.748
9.43	0.779
9.53	0.876
9.59	0.852
9.65	0.803
9.69	0.885
9.77	0.902
9.86	0.878
9.95	0.672
10.05	0.613
10.17	0.721
10.28	0.678
10.53	0.832
10.65	0.857
10.87	0.835
11.03	0.902
11.22	0.916
11.44	0.899
11.81	0.773
11.92	0.861
12.11	0.697
12.30	0.891
12.53	0.922
12.71	0.896
13.09	0.584
12.80	0.924
13.62	0.955
13.99	0.714
14.12	0.534

λ	τ
CURVE 20(CONT.)	
14.31	0.947
14.64	0.980
15.65	0.975
18.21	0.963
19.53	0.906
19.92	0.906
20.53	0.872
20.88	0.925
22.03	0.930
23.31	0.911
23.31	0.879
23.92	0.872
25.00	0.828
CURVE 21	
T = 293.	
2.50	0.914
2.63	0.919
2.72	0.919
2.77	0.903
2.84	0.892
2.89	0.883
2.92	0.874
2.96	0.886
3.08	0.897
3.23	0.905
3.26	0.874
3.29	0.839
3.32	0.709
3.34	0.600
3.36	0.671
3.38	0.591
3.39	0.470
3.40	0.527
3.43	0.527
3.46	0.702
3.48	0.784
3.52	0.735
3.56	0.902

λ	τ
CURVE 21(CONT.)	
3.61	0.921
3.74	0.935
4.18	0.943
5.00	0.945
5.13	0.943
5.26	0.952
5.38	0.952
5.48	0.940
5.59	0.917
5.65	0.896
5.70	0.798
5.72	0.405
5.75	0.098
5.76	0.071
5.79	0.133
5.88	0.713
5.93	0.690
6.11	0.796
6.14	0.851
6.24	0.871
6.29	0.903
6.37	0.910
6.51	0.910
6.62	0.889
6.68	0.843
6.70	0.598
6.73	0.625
6.79	0.651
6.84	0.600
6.88	0.479
6.91	0.507
6.96	0.494
7.03	0.768
7.07	0.782
7.12	0.765
7.22	0.637
7.27	0.736
7.46	0.802
7.59	0.802
7.70	0.768

λ	τ
CURVE 21(CONT.)	
7.78	0.677
7.81	0.536
7.85	0.499
7.91	0.536
7.97	0.501
8.04	0.415
8.20	0.642
8.26	0.597
8.35	0.318
8.44	0.369
8.54	0.350
8.67	0.198
8.83	0.502
8.92	0.842
9.14	0.771
9.26	0.776
9.43	0.749
9.52	0.825
9.71	0.839
9.86	0.850
10.00	0.817
10.24	0.783
10.37	0.624
10.46	0.763
10.60	0.835
10.76	0.863
10.99	0.797
11.15	0.859
11.19	0.894
11.35	0.903
11.56	0.884
11.67	0.863
11.79	0.847
11.92	0.800
12.02	0.864
12.11	0.859
12.25	0.878
12.39	0.865
12.59	0.889
12.85	0.883

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

CURVE 21 (CONT.)

λ	τ
12.59	0.889
12.85	0.883
13.07	0.840
13.35	0.745
13.42	0.857
13.95	0.876
14.14	0.863
14.29	0.732
14.49	0.880
15.87	0.689
17.64	0.862
18.80	0.853
19.80	0.632
20.49	0.324
20.92	0.796
21.51	0.816
22.62	0.803
23.64	0.794
25.00	0.737

CURVE 22
T = 293.

λ	τ
2.275	0.000
1.106	0.000
1.204	0.998
1.305	0.983
1.404	0.010
1.501	0.010
1.603	0.010
1.702	0.010
1.804	0.010
1.899	0.010
2.005	0.010
2.099	0.010
2.196	0.010
2.298	0.977
2.400	0.010
2.499	0.010
2.596	0.010

CURVE 22 (CONT.)

λ	τ
2.699	0.010
2.800	0.827

CURVE 23
T = 293.

λ	τ
2.50	0.928
2.51	0.926
2.53	0.915
2.54	0.932
2.57	0.932
2.59	0.922
2.66	0.935
2.68	0.925
2.70	0.936
2.73	0.902
2.76	0.887
2.79	0.899
2.83	0.872
2.86	0.873
2.93	0.830
2.99	0.824
3.10	0.846
3.17	0.857
3.23	0.825
3.28	0.790
3.31	0.753
3.33	0.598
3.34	0.507
3.38	0.456
3.41	0.531
3.43	0.624
3.45	0.681
3.48	0.681
3.52	0.827
3.56	0.881
3.67	0.919
3.76	0.913
3.87	0.913
3.93	0.923

CURVE 23 (CONT.)

λ	τ
4.17	0.923
4.23	0.954
4.35	0.937
4.47	0.948
4.75	0.937
5.00	0.934
5.13	0.927
5.28	0.927
5.41	0.906
5.47	0.889
5.53	0.774
5.58	0.746
5.64	0.594
5.68	0.524
5.72	0.225
5.74	0.106
5.78	0.087
5.80	0.122
5.88	0.396
5.93	0.547
5.96	0.608
6.00	0.657
6.05	0.664
6.08	0.650
6.12	0.673
6.16	0.771
6.21	0.794
6.24	0.772
6.27	0.820
6.31	0.807
6.36	0.842
6.40	0.824
6.44	0.824
6.49	0.811
6.56	0.822
6.61	0.798
6.65	0.737
6.68	0.744
6.73	0.697
6.78	0.577

CURVE 23 (CONT.)

λ	τ
6.81	0.500
6.87	0.462
6.96	0.505
7.03	0.692
7.13	0.683
7.23	0.520
7.29	0.552
7.34	0.632
7.41	0.666
7.47	0.632
7.52	0.569
7.58	0.552
7.67	0.404
7.70	0.314
7.73	0.256
7.79	0.244
7.90	0.287
8.04	0.392
8.14	0.424
8.36	0.336
8.45	0.336
8.63	0.286
8.83	0.386
8.90	0.390
9.02	0.591
9.15	0.642
9.21	0.593
9.25	0.505
9.32	0.482
9.41	0.649
9.49	0.664
9.59	0.596
9.70	0.566
9.80	0.577
9.92	0.723
10.21	0.755
10.46	0.700
10.60	0.746
10.76	0.808
10.89	0.793

CURVE 23 (CONT.)

λ	τ
11.11	0.822
11.44	0.858
11.71	0.819
11.98	0.842
12.18	0.797
12.35	0.845
12.55	0.825
12.80	0.825
13.02	0.809
13.19	0.699
13.48	0.676
13.74	0.844
14.06	0.808
14.29	0.750
14.43	0.885
14.97	0.920
15.29	0.899
15.43	0.917
15.65	0.930
16.45	0.906
17.42	0.914
17.70	0.898
18.12	0.909
18.45	0.891
19.31	0.907
19.72	0.889
20.33	0.888
20.53	0.869
21.46	0.869
22.57	0.823
23.53	0.789
24.33	0.718
25.00	0.718

CURVE 24
T = 293.

λ	τ
2.50	0.936
2.55	0.950
2.69	0.950

CURVE 24 (CONT.)

λ	τ
2.76	0.953
2.80	0.925
2.85	0.865
2.91	0.824
2.95	0.830
3.06	0.830
3.16	0.850
3.22	0.850
3.29	0.797
3.32	0.725
3.37	0.417
3.40	0.326
3.41	0.230
3.43	0.266
3.47	0.475
3.51	0.411
3.53	0.711
3.56	0.812
3.61	0.876
3.66	0.877
3.77	0.910
3.87	0.910
4.18	0.940
4.23	0.924
4.27	0.937
4.32	0.930
4.38	0.946
4.62	0.954
5.00	0.954
5.13	0.956
5.27	0.953
5.28	0.944
5.32	0.953
5.37	0.942
5.39	0.831
5.42	0.910
5.45	0.928
5.49	0.884
5.56	0.782
5.58	0.626

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 24(CONT.)		CURVE 24(CONT.)		CURVE 24(CONT.)		CURVE 25(CONT.)		CURVE 25(CONT.)		CURVE 25(CONT.)	
5.61	0.654	7.47	0.628	16.10	0.919	3.52	0.787	6.30	0.727	12.17	0.811
5.63	0.521	7.65	0.516	16.89	0.902	3.57	0.849	6.44	0.773	12.66	0.841
5.65	0.551	7.75	0.484	18.28	0.902	3.68	0.869	6.54	0.793	12.74	0.776
5.68	0.511	7.88	0.423	18.76	0.854	3.87	0.874	6.68	0.768	12.95	0.787
5.71	0.257	7.96	0.350	19.08	0.884	3.90	0.896	6.76	0.699	13.21	0.773
5.75	0.128	8.14	0.419	19.96	0.892	3.96	0.871	6.87	0.303	13.42	0.828
5.81	0.211	8.29	0.362	21.51	0.892	4.05	0.895	6.96	0.391	13.76	0.859
5.88	0.434	8.48	0.300	23.09	0.849	4.10	0.888	7.01	0.343	14.03	0.896
5.92	0.604	8.61	0.314	23.53	0.806	4.16	0.888	7.06	0.466	14.27	0.885
5.97	0.696	8.67	0.335	24.27	0.788	4.21	0.906	7.12	0.483	14.51	0.897
6.02	0.744	8.90	0.383	25.00	0.769	4.28	0.875	7.12	0.634	15.36	0.871
6.08	0.744	9.03	0.389			4.35	0.875	7.37	0.612	16.03	0.858
6.11	0.733	9.15	0.457	CURVE 25		4.39	0.798	7.49	0.639	16.64	0.882
6.17	0.753	9.18	0.497	T = 293.		4.44	0.331	7.69	0.639	17.36	0.809
6.22	0.741	9.31	0.529			4.46	0.534	7.85	0.590	17.92	0.835
6.25	0.757	9.46	0.561	2.50	0.908	4.50	0.499	7.92	0.626	18.42	0.798
6.27	0.783	9.63	0.516	2.64	0.922	4.52	0.812	8.03	0.626	19.12	0.844
5.32	0.790	9.76	0.534	2.78	0.905	4.56	0.768	8.17	0.576	21.28	0.917
6.37	0.848	9.82	0.615	2.84	0.905	4.60	0.894	8.31	0.585	22.99	0.876
6.41	0.856	9.97	0.684	2.86	0.880	4.69	0.922	8.40	0.629	23.53	0.837
6.44	0.869	10.19	0.719	2.89	0.813	4.76	0.909	8.51	0.591	25.00	0.837
6.53	0.884	10.33	0.700	2.91	0.834	4.87	0.926	8.67	0.704		
6.57	0.864	10.54	0.707	2.95	0.744	4.93	0.916	8.83	0.756	CURVE 26	
6.61	0.303	10.81	0.757	2.96	0.726	5.00	0.922	8.92	0.734	T = 293.	
6.67	0.825	11.12	0.660	2.98	0.736	5.07	0.921	9.03	0.754		
6.72	0.757	11.25	0.727	2.99	0.772	5.15	0.894	9.16	0.734	2.50	0.915
6.76	0.693	11.44	0.760	3.02	0.808	5.26	0.881	9.31	0.712	2.54	0.916
6.80	0.504	11.68	0.750	3.06	0.776	5.35	0.917	9.45	0.728	2.57	0.930
6.81	0.451	11.83	0.783	3.09	0.791	5.55	0.914	9.58	0.704	2.61	0.923
6.85	0.437	12.24	0.801	3.13	0.791	5.63	0.877	9.67	0.741	2.64	0.943
6.89	0.458	12.42	0.833	3.17	0.811	5.68	0.842	9.72	0.768	2.76	0.943
6.89	0.486	12.87	0.833	3.21	0.751	5.74	0.538	10.05	0.768	2.79	0.927
6.98	0.539	13.02	0.805	3.24	0.788	5.77	0.446	10.16	0.738	2.85	0.920
7.02	0.651	13.18	0.795	3.28	0.739	5.82	0.642	10.31	0.437	2.87	0.871
7.09	0.674	13.57	0.843	3.31	0.739	5.88	0.689	10.44	0.399	2.88	0.836
7.15	0.656	13.93	0.659	3.33	0.647	5.96	0.659	10.71	0.701	2.90	0.831
7.25	0.501	14.16	0.851	3.40	0.443	6.03	0.685	10.89	0.795	2.92	0.857
7.31	0.535	14.60	0.895	3.42	0.496	6.08	0.595	11.19	0.795	2.94	0.824
7.34	0.592	15.04	0.919	3.44	0.649	6.15	0.562	11.61	0.837	2.97	0.714
7.41	0.604	15.62	0.911	3.48	0.675	6.23	0.677	11.98	0.784	3.00	0.805

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 26(CONT.)		CURVE 26(CONT.)		CURVE 26(CONT.)		CURVE 26(CONT.)		CURVE 27(CONT.)		CURVE 27(CONT.)	
3.20	0.768	5.30	0.911	7.87	0.611	14.16	0.897	4.65	0.839	10.64	0.903
3.22	0.760	5.36	0.937	7.92	0.678	14.41	0.866	5.21	0.854	11.75	0.934
3.25	0.767	5.41	0.957	8.01	0.650	14.79	0.875	5.57	0.824	12.52	0.888
3.29	0.705	5.50	0.957	8.08	0.670	15.22	0.853	5.68	0.690	13.05	0.932
3.32	0.733	5.53	0.935	8.16	0.614	15.72	0.825	5.70	0.553	13.45	0.932
3.35	0.551	5.59	0.956	8.27	0.654	16.31	0.827	5.75	0.478	13.73	0.943
3.38	0.413	5.69	0.938	8.35	0.704	16.64	0.859	5.82	0.596	13.97	0.930
3.40	0.349	5.76	0.879	8.45	0.721	17.21	0.774	5.87	0.654	14.15	0.930
3.44	0.509	5.81	0.866	8.54	0.721	17.67	0.736	5.89	0.792	14.50	0.932
3.46	0.622	5.89	0.846	8.63	0.750	18.21	0.764	6.02	0.661	15.00	0.895
3.49	0.513	5.97	0.781	8.70	0.788	18.69	0.699	6.14	0.798		
3.53	0.754	6.04	0.759	8.87	0.757	18.98	0.713	6.30	0.320	CURVE 28	
3.57	0.823	6.08	0.654	8.98	0.711	19.42	0.746	6.38	0.839	T = 293.	
3.64	0.884	6.10	0.561	9.15	0.722	19.60	0.805	6.60	0.809		
3.72	0.884	6.13	0.561	9.39	0.674	20.12	0.861	6.77	0.704	3.12	0.300
3.77	0.895	6.17	0.508	9.49	0.687	20.83	0.848	6.81	0.548	3.19	0.800
3.83	0.873	6.19	0.615	9.62	0.654	21.55	0.897	7.03	0.459	3.26	0.768
3.87	0.894	6.25	0.693	9.72	0.705	22.27	0.858	7.00	0.762	3.34	0.685
3.91	0.894	6.32	0.761	9.81	0.735	23.20	0.893	7.09	0.807	3.41	0.277
3.94	0.911	6.38	0.744	9.87	0.718	23.20	0.854	7.18	0.781	3.44	0.435
3.98	0.890	6.44	0.804	10.03	0.739	24.04	0.831	7.26	0.677	3.44	0.499
4.05	0.903	6.51	0.846	10.17	0.687	24.51	0.756	7.36	0.658	3.46	0.630
4.19	0.908	6.65	0.801	10.33	0.353	25.00	0.769	7.48	0.670	3.49	0.624
4.25	0.862	6.70	0.771	10.47	0.222			7.55	0.733	3.51	0.716
4.35	0.876	6.73	0.721	10.73	0.623	CURVE 27		7.67	0.733	3.51	0.814
4.40	0.839	6.77	0.706	10.85	0.703	T = 293.		7.84	0.672	3.62	0.839
4.44	0.162	6.80	0.560	10.92	0.755			8.01	0.630	3.69	0.850
4.48	0.410	6.89	0.135	11.09	0.742	2.49	0.703	8.31	0.630	3.76	0.837
4.50	0.345	6.93	0.260	11.33	0.767	2.71	0.732	8.45	0.664	3.85	0.850
4.52	0.784	6.97	0.297	11.56	0.750	2.98	0.696	8.58	0.655	4.03	0.849
4.57	0.732	7.03	0.204	11.61	0.804	3.17	0.732	8.67	0.708	4.16	0.875
4.61	0.871	7.07	0.353	11.82	0.779	3.28	0.706	8.72	0.820	4.29	0.875
4.64	0.924	7.10	0.339	12.05	0.731	3.45	0.611	8.80	0.852	4.34	0.858
4.71	0.948	7.19	0.642	12.14	0.783	3.58	0.771	9.01	0.777	4.39	0.821
4.81	0.954	7.39	0.575	12.36	0.811	3.83	0.809	9.28	0.708	4.42	0.613
4.88	0.929	7.45	0.619	12.84	0.764	4.18	0.816	9.35	0.708	4.42	0.423
5.00	0.957	7.53	0.632	13.21	0.697	4.33	0.830	9.47	0.747	4.45	0.669
5.07	0.965	7.63	0.632	13.51	0.770	4.43	0.751	9.63	0.747	4.49	0.528
5.14	0.937	7.71	0.647	13.77	0.786	4.50	0.552	9.77	0.828	4.49	0.782
5.22	0.874	7.75	0.627	13.93	0.862	4.53	0.801	10.08	0.877	4.51	0.862

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 23 (CONT.)		CURVE 28 (CONT.)		CURVE 29 (CONT.)		CURVE 30		CURVE 30 (CONT.)		CURVE 30 (CONT.)	
4.58	0.915	9.38	0.558	6.27	0.573	T = 293.		3.68	0.738	5.41	0.723
4.69	0.944	9.50	0.695	6.37	0.591	2.52	0.788	3.71	0.794	5.45	0.762
4.99	0.954	9.60	0.750	6.51	0.539	2.57	0.796	3.78	0.800	5.48	0.748
5.63	0.954	9.76	0.817	6.60	0.445	2.61	0.822	3.81	0.776	5.50	0.690
5.73	0.922	10.02	0.885	6.71	0.445	2.66	0.833	3.84	0.785	5.59	0.537
5.88	0.916	10.23	0.894	6.84	0.187	2.70	0.827	3.88	0.769	5.66	0.338
6.05	0.944	10.70	0.911	7.01	0.499	2.72	0.839	3.91	0.793	5.71	0.154
6.24	0.944	11.11	0.898	7.16	0.409	2.75	0.831	3.95	0.745	5.72	0.067
6.29	0.959			7.26	0.299	2.79	0.783	4.00	0.792	5.77	0.004
6.54	0.917	CURVE 29		7.38	0.415	2.82	0.811	4.09	0.792	5.87	0.004
6.67	0.887	T = 293.		7.54	0.485	2.86	0.799	4.13	0.800	5.90	0.032
6.73	0.756			7.79	0.394	2.89	0.813	4.28	0.781	5.95	0.141
6.78	0.471	2.48	0.490	7.94	0.258	2.92	0.803	4.33	0.791	6.01	0.347
6.85	0.118	2.66	0.457	8.00	0.189	2.94	0.607	4.38	0.732	6.05	0.373
6.92	0.429	2.78	0.358	8.18	0.351	2.98	0.795	4.41	0.802	6.08	0.198
6.97	0.653	2.84	0.319	8.20	0.419	3.01	0.742	4.53	0.810	6.10	0.009
7.01	0.773	2.98	0.364	8.31	0.522	3.03	0.792	4.55	0.823	6.11	0.000
7.07	0.809	3.10	0.424	8.47	0.548	3.06	0.801	4.59	0.823	6.14	0.005
7.17	0.710	3.22	0.394	8.69	0.623	3.13	0.792	4.62	0.797	6.22	0.438
7.26	0.579	3.34	0.279	8.98	0.469	3.15	0.778	4.66	0.752	6.24	0.492
7.27	0.482	3.44	0.423	9.31	0.364	3.16	0.751	4.70	0.761	6.28	0.522
7.35	0.455	3.53	0.528	9.53	0.380	3.21	0.702	4.73	0.751	6.32	0.535
7.46	0.526	3.85	0.555	9.66	0.380	3.25	0.462	4.74	0.773	6.35	0.532
7.51	0.615	4.19	0.555	9.76	0.459	3.26	0.637	4.77	0.789	6.42	0.617
7.65	0.615	4.27	0.510	9.92	0.609	3.30	0.511	4.81	0.761	6.44	0.605
7.76	0.641	4.39	0.293	10.29	0.650	3.32	0.161	4.88	0.805	6.52	0.583
7.93	0.535	4.41	0.534	10.74	0.679	3.34	0.171	4.91	0.796	6.56	0.544
7.99	0.546	4.45	0.599	11.01	0.736	3.35	0.031	4.95	0.682	6.60	0.541
8.05	0.585	4.58	0.627	11.46	0.753	3.39	0.091	4.99	0.698	6.65	0.527
8.21	0.617	4.95	0.607	11.91	0.673	3.40	0.003	5.01	0.684	6.68	0.490
8.37	0.702	5.15	0.607	12.21	0.712	3.41	0.145	5.01	0.643	6.72	0.419
8.45	0.740	5.30	0.597	12.40	0.712	3.43	0.066	5.04	0.636	6.75	0.256
8.46	0.782	5.43	0.597	12.64	0.681	3.46	0.288	5.07	0.727	6.76	0.192
8.56	0.829	5.57	0.532	13.06	0.681	3.47	0.298	5.12	0.761	6.80	0.126
8.69	0.860	5.66	0.222	13.35	0.690	3.51	0.478	5.15	0.745	6.80	0.061
8.79	0.849	5.69	0.396	13.57	0.621	3.53	0.293	5.19	0.738	6.84	0.043
8.87	0.772	5.77	0.447	13.90	0.704	3.57	0.695	5.21	0.657	6.84	0.008
9.00	0.615	5.77	0.545	14.08	0.704	3.59	0.710	5.26	0.681	6.86	0.004
9.18	0.568	5.85	0.583	14.48	0.693	3.61	0.751	5.31	0.579	6.98	0.004
9.23	0.495	6.13	0.483	15.00	0.667	3.65	0.775	5.37	0.711	7.00	0.015

TABLE 15-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF ACRYLIC RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ
CURVE 30(CONT.)		CURVE 30(CONT.)		CURVE 30(CONT.)		CURVE 30(CONT.)	
7.00	0.051	10.05	0.146	15.39	0.165	21.87	0.678
7.06	0.155	10.09	0.201	15.64	0.531	22.11	0.673
7.10	0.171	10.15	0.133	15.75	0.673	22.28	0.667
7.14	0.072	10.18	0.103	15.84	0.704	22.41	0.652
7.19	0.274	10.25	0.335	15.94	0.725	23.06	0.624
7.20	0.285	10.30	0.347	16.03	0.750	23.19	0.604
7.24	0.176	10.35	0.329	16.31	0.755	23.48	0.596
7.24	0.038	10.49	0.033	16.44	0.718	23.98	0.586
7.27	0.073	10.59	0.007	16.56	0.464	24.08	0.560
7.31	0.309	10.59	0.006	16.61	0.359	24.39	0.532
7.33	0.329	10.66	0.000	16.66	0.347	24.56	0.516
7.39	0.231	10.79	0.000	16.72	0.359	24.56	0.495
7.44	0.346	10.82	0.029	16.78	0.476	24.65	0.480
7.49	0.003	10.92	0.491	16.85	0.419	24.81	0.468
7.71	0.001	11.01	0.633	16.90	0.402		
7.75	0.015	11.09	0.681	16.96	0.421		
7.80	0.221	11.22	0.725	16.96	0.545		
7.85	0.333	11.38	0.741	17.05	0.685		
7.87	0.389	11.57	0.741	17.21	0.755		
7.90	0.402	11.80	0.666	17.33	0.780		
7.93	0.402	11.95	0.228	17.55	0.783		
8.01	0.358	11.95	0.061	17.70	0.789		
8.10	0.201	12.00	0.054	18.09	0.788		
8.13	0.132	12.05	0.086	18.46	0.788		
8.16	0.202	12.24	0.006	18.68	0.780		
8.20	0.357	12.33	0.056	18.91	0.765		
8.26	0.010	12.43	0.492	19.13	0.736		
8.73	0.010	12.57	0.666	19.31	0.696		
8.91	0.250	12.68	0.745	19.50	0.583		
9.03	0.474	12.78	0.769	19.65	0.454		
9.15	0.533	12.94	0.784	19.74	0.443		
9.34	0.653	13.65	0.801	19.82	0.425		
9.45	0.665	13.75	0.812	19.97	0.456		
9.54	0.658	14.25	0.812	20.01	0.500		
9.55	0.561	14.43	0.801	20.08	0.529		
9.63	0.487	14.60	0.761	20.19	0.584		
9.79	0.315	14.77	0.666	20.34	0.632		
9.90	0.336	14.95	0.468	20.47	0.655		
9.93	0.190	15.08	0.219	20.67	0.671		
9.96	0.199	15.32	0.156	20.97	0.678		

4.16 Lucite

Lucite is a propriatory acrylic resin, poly(methyl methacrylate), manufactured by DuPont Co. "Plexiglas" and "Perspex" are essentially the same material manufactured by Rohm and Haas Co. and Imperical Chemical Industrial Chemicals Ltd. respectively.

Lucite is a rigid, crystal-clear thermoplastic material with excellent mechanical and chemical properties. It has the best resistance to the effects of sunlight and outdoor weathering among all the transparent plastics. Industrial uses include optical applications such as in TV screens, automobile taillights, and lenses for cameras and slide viewers.

Lucite acrylic resins can be easily processed by all fabricating techniques currently practiced in the industry. They can be injection molded, blow molded, compression molded, and extruded. It also can be machined, drilled, threaded, and routed with standard wood and metal-working equipment.

The polymerization of Lucite is carried out in water suspension with peroxide catalyst. The resulting polymer is washed, dried and blended with plasticizer and colorants before pelletizing for use as molding powders.

$$CH_2 = \overset{CH_3}{\overset{|}{C}} - \overset{O}{\overset{\|}{C}} - OCH_3 \xrightarrow[\text{peroxide} \atop H_2O]{80\text{-}100\ C} [-CH_2 - \underset{COOCH_3}{\underset{|}{C}}CH_3 -]_n$$

Polymethyl methacrylate

The molecular weight of Lucite is of the order of 5×10^5 to over 10^6 (degree of polymerisation approximately 5000-10000). According to x-ray data, Lucite is substantially amorphous materials. It is soluable in aromatic and most chlorinated hydrocarbons (toulene, ethylene, dichloride, chloroform), esters (ethyl acetate), leetones, tetrahydrofuran. It will be swollen by alchols, phenols, ether and carbon tetrachloride. It can be decomposed by conc. oxidizing acids (HNO_3, H_2SO_4, H_2CrO_4) and alcoholic alkalis.

Lucite has density 1.18-1.19 gm cm^{-3}, has the second order (glass) transition temperature at about 378 K, softens above 397 K and decomposes around 520 K. The maximum service temperature is 350 K. Its dielectric constants are 2.7-3.9 over the range $50\text{-}10^5$ Hz. Its resistivity is about $10^{14}\text{-}10^{15}$ ohm-cm. Its dielectric strength is about 16 KV/mm for 3 mm sheet.

Lucite has specific heat 0.35, thermal conductivity 0.00188 W cm^{-1} K^{-1}, and thermal expansion coefficient 0.75×10^{-4} K^{-1} at 293 K (1.05×10^{-4}/K at 350 K). It shrinks 0.2-0.7% when molding.

a. Normal Spectral Emittance (Wavelength Dependence)

There is no data on the normal spectral emittance of Lucite available. However, Pregelhof, Francy, and Haas [T77125] used a one-dimensional model, assuming uniform properties, and gave the emittance $\epsilon(\lambda)$, the absorptance $\alpha(\lambda)$, the transmittance $\tau(\lambda)$, and the reflectance $\rho(\lambda)$ of a polymer sheet in the following expressions:

$$\epsilon(\lambda) = \alpha(\lambda) = \frac{(1-R)\,[(1+R)\sinh ad + (1-R)\,(\cosh ad - 1)]}{(1+R^2)\sinh ad + (1-R^2)\cosh ad} \tag{4.16-1}$$

$$\tau(\lambda) = \frac{(1-R)^2}{(1+R^2)\sinh ad + (1-R^2)\cosh ad} \tag{4.16-2}$$

$$\rho(\lambda) = \frac{2R\,[R\sinh ad + (1-R)\cosh ad]}{(1+R^2)\sinh ad + (1-R^2)\cosh ad} \tag{4.16-3}$$

where $R = (n-1/n+1)^2$ and n is the refractive index, d is the thickness of the sample, and a is the absorption coefficient.

For the Lucite bulk material, it can be assumed that

$$e^{ad} \gg R\,e^{-ad} \tag{4.16-4}$$

which enables eqs. (4.16-1, 4.16-2, and 4.16-3) to become the following:

$$\epsilon(\lambda) = \alpha(\lambda) \cong (1-R)\,[1 - (1-R)\,e^{-ad} - R\,e^{-2ad}] \tag{4.16-5}$$

$$\tau(\lambda) \cong (1-R)^2\,e^{-ad} \tag{4.16-6}$$

$$\rho(\lambda) \cong R\,[1 + (1-2R)\,e^{-2ad}] \tag{4.16-7}$$

By using these equations together with the experimental data of transmittance and reflectance, the emittance can be calculated. Here we used d = 3.2 mm for calculation. The calculated results of the normal spectral emittance for Lucite sample with thickness 3.2 mm at 293 K are shown in Table 16-1 and Fig. 16-1 with an estimated uncertainty of about ±20%.

TABLE 16-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε
THICKNESS 3.2MM		THICKNESS 3.2MM		THICKNESS 3.2MM	
T = 293		T = 293 (CONT.)		T = 293 (CONT.)	
0.240	0.919	1.92	0.430	9.00	0.964
0.259	0.901	1.95	0.430	9.50	0.967
0.290	0.910	2.00	0.371	10.00	0.967
0.350	0.910	2.09	0.699	10.50	0.969
0.364	0.902	2.13	0.811	11.00	0.967
0.369	0.890	2.20	0.950	11.80	0.971
0.374	0.850	2.43	0.964	12.00	0.968
0.376	0.772	2.53	0.931	12.70	0.977
0.380	0.145	2.58	0.926	13.00	0.968
0.390	0.100	2.63	0.927	13.50	0.970
0.403	0.040	2.66	0.922	14.00	0.967
0.422	0.012	2.80	0.965	14.50	0.963
0.510	0.012	3.00	0.964	15.00	0.963
0.700	0.012	3.07	0.974		
0.741	0.009	3.12	0.963		
0.760	0.007	3.20	0.966		
0.788	0.007	3.25	0.973		
0.815	0.005	3.41	0.965		
0.844	0.020	3.54	0.968		
0.890	0.036	3.59	0.964		
1.000	0.034	3.60	0.970		
1.181	0.253	3.64	0.971		
1.214	0.111	3.95	0.967		
1.270	0.039	4.22	0.963		
1.318	0.074	4.16	0.967		
1.347	0.250	4.60	0.968		
1.367	0.311	4.70	0.972		
1.400	0.253	5.00	0.971		
1.500	0.381	5.23	0.974		
1.607	0.148	5.62	0.976		
1.662	0.500	5.78	0.961		
1.677	0.345	6.00	0.968		
1.700	0.776	6.50	0.973		
1.727	0.732	6.75	0.972		
1.754	0.510	7.00	0.970		
1.825	0.341	7.50	0.977		
1.877	0.365	8.00	0.973		
1.890	0.617	8.50	0.962		
1.900	0.700	8.75	0.957		

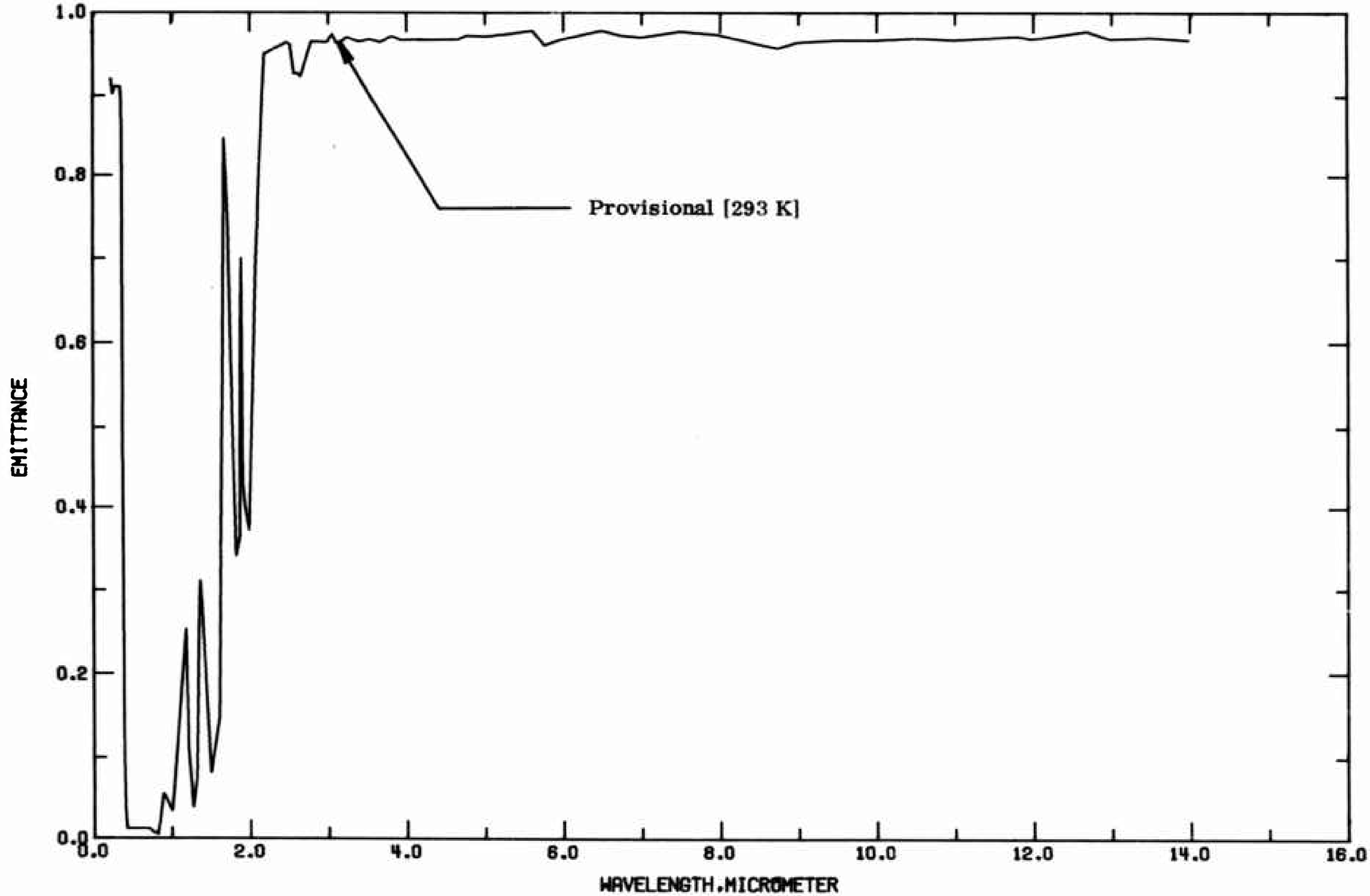


FIGURE 16-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE).

b. Normal Spectral Reflectance (Wavelength Dependence)

Only Byrne and Mancinilli [T32388] have measured the normal spectral reflectance for a 3.2 mm thick specimen in the 0.24 to 2.6 μm region. Grim, Linfored, Dillow, Spinak, and Mills [A00001] measured the angular spectral reflectance for a 290 mil thick disk of Plexiglas in the 2-15 μm region with the incident angle of 15° and 45°. The reflectance value increases slightly with the increase of the incident angle.

Pregelhof, Francy, and Haas [T77125] calculated the absorption coefficient $a = 20\ cm^{-1}$ or larger in the wavelength region $\lambda > 4\ \mu m$. Then, Eq. (4.16-7) becomes

$$\rho(\lambda) \approx R = (n - 1)^2/(n + 1)^2 \qquad (4.16\text{-}8)$$

which is independent of the thickness of the sample and depends only on index of refraction. However, the data of index of refraction is not available in the wavelength region above 1 μm. Thus, Eq. (4.16-8) is not applicable in this case.

Based on the three sets of experimental data and Eq. (4.16-7), the provisional values of normal spectral reflectance are presented in Table 16-2 and Figure 16-2 with an estimated uncertainty of about ±30%.

TABLE 16-2. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF LUCITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ
PLEXIGLAS		PLEXIGLAS		PLEXIGLAS	
T = 293		T = 293 (CONT.)		T = 293 (CONT.)	
0.24	0.081	3.25	0.030	14.3	0.037
0.39	0.082	3.41	0.035	15.0	0.037
0.51	0.079	3.54	0.032		
0.80	0.075	3.68	0.036		
0.94	0.072	3.80	0.030		
1.00	0.070	3.84	0.029		
1.08	0.070	3.95	0.033		
1.19	0.063	4.00	0.032		
1.27	0.069	4.16	0.033		
1.33	0.060	4.68	0.032		
1.46	0.067	4.78	0.025		
1.54	0.073	5.00	0.025		
1.60	0.069	5.29	0.026		
1.65	0.047	5.62	0.022		
1.79	0.061	5.78	0.039		
1.82	0.060	6.00	0.032		
1.89	0.049	6.50	0.022		
1.96	0.060	6.75	0.028		
2.00	0.047	7.00	0.030		
2.13	0.046	7.30	0.027		
2.23	0.050	7.50	0.023		
2.48	0.036	7.75	0.025		
2.53	0.035	8.00	0.027		
2.58	0.028	8.50	0.038		
2.63	0.022	8.75	0.043		
2.66	0.036	9.00	0.036		
2.69	0.030	9.50	0.033		
2.70	0.038	9.73	0.031		
2.73	0.029	10.00	0.033		
2.76	0.025	10.50	0.031		
2.80	0.035	11.0	0.033		
2.84	0.029	11.8	0.029		
2.90	0.038	12.0	0.032		
2.96	0.026	12.4	0.035		
3.00	0.035	12.7	0.033		
3.07	0.025	13.0	0.032		
3.12	0.037	13.5	0.030		
3.17	0.030	13.8	0.030		
3.20	0.034	14.0	0.033		

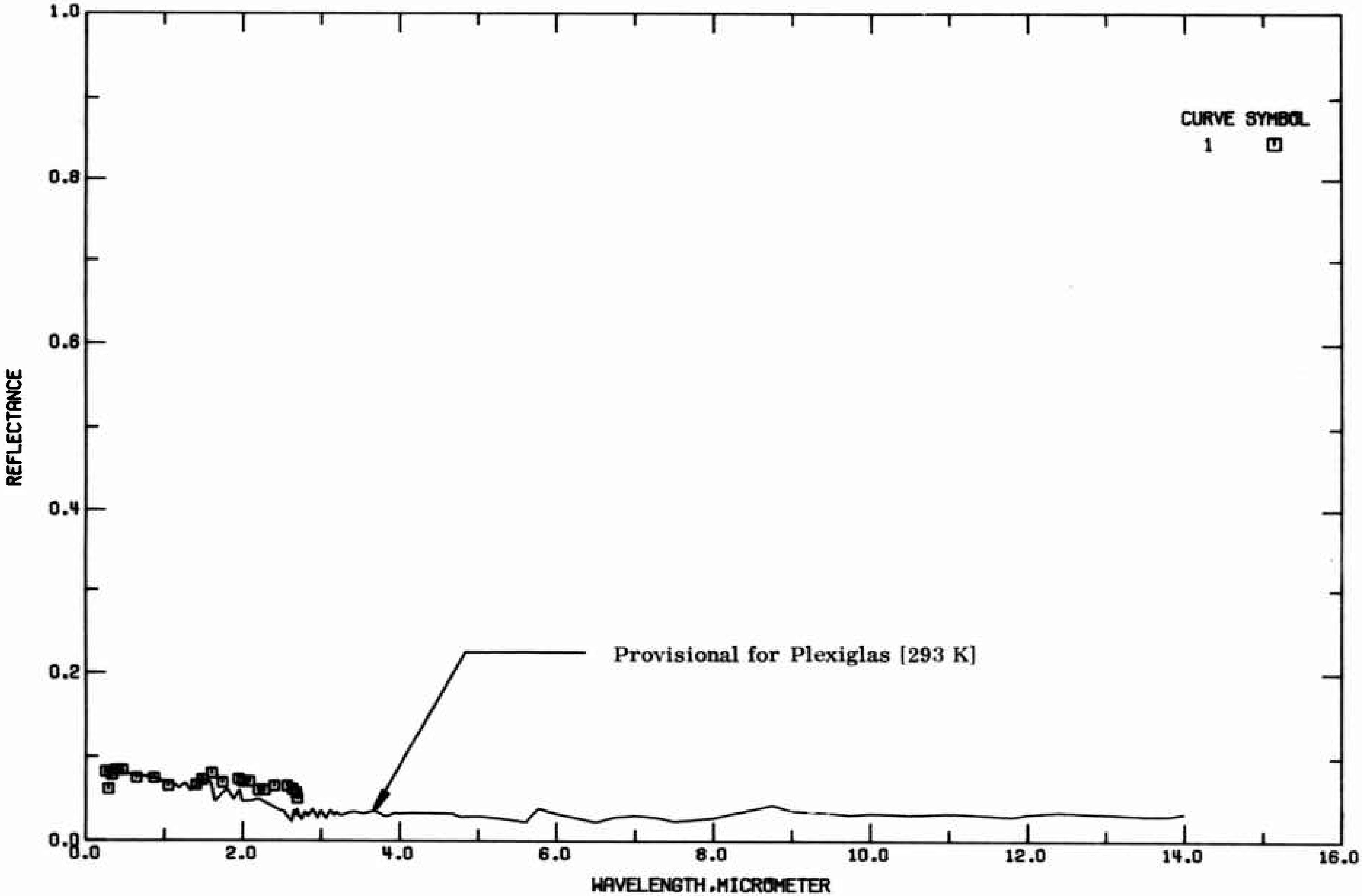


FIGURE 16-2. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF LUCITE (WAVELENGTH DEPENDENCE).

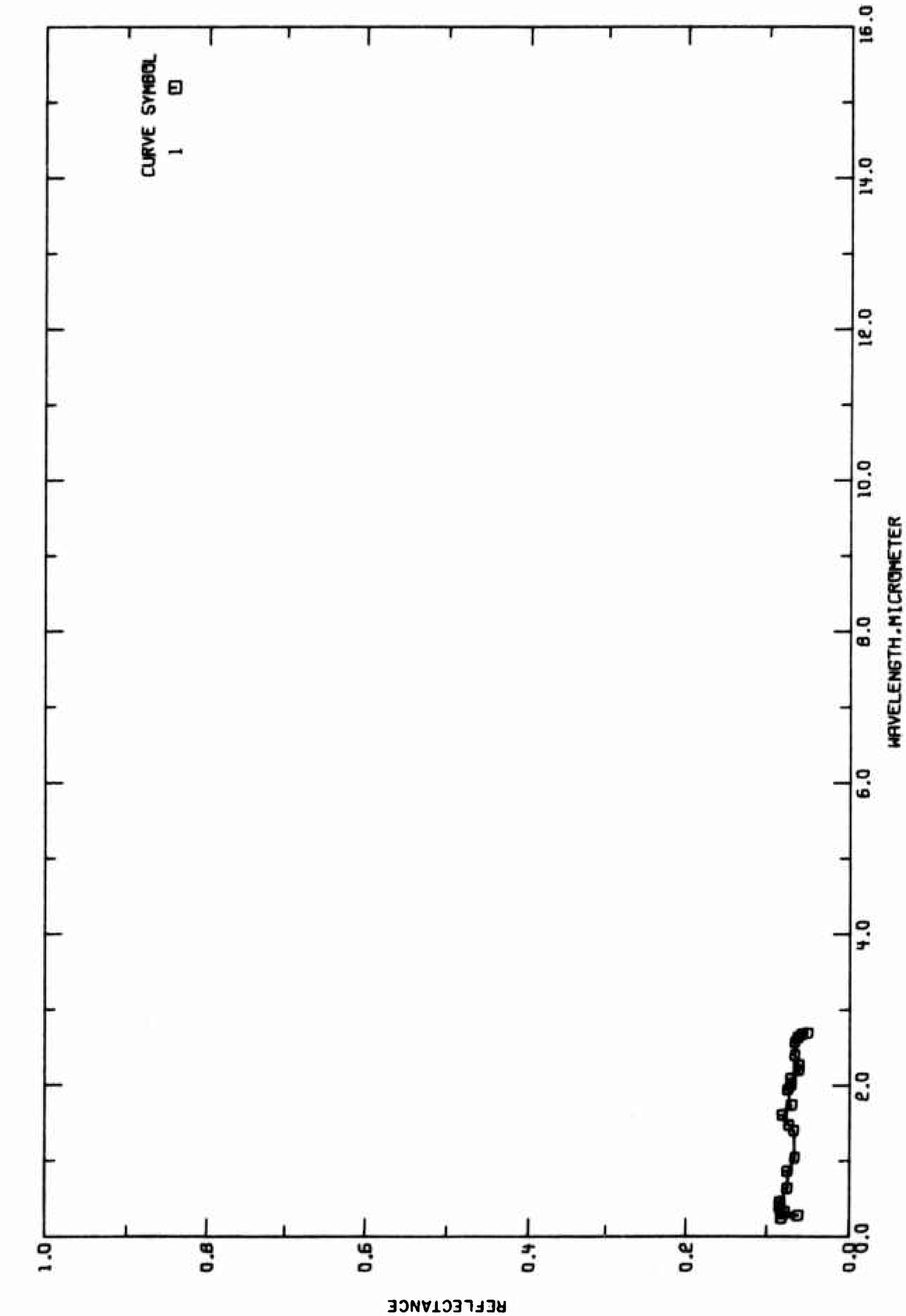


FIGURE 16-3. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF LUCITE (WAVELENGTH DEPENDENCE).

TABLE 16-3. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF LUCITE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T32338	Byrne, R.F. and Mancinilli, L.N.	1954	0.24-2.6	293	Lucite	Approx. 1/8 in. thick; General Electric Spectrometer, Beckman Spectrometer and Perkin-Elmer Spectrometer were used; data extracted from the smooth curve; $\theta=0°$, $\omega'=2\pi$; reported error $\leq 5\%$.

TABLE 16-4. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF LUCITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 293.	
0.241	0.082
0.279	0.062
0.326	0.079
0.326	0.079
0.376	0.084
0.461	0.084
0.636	0.075
0.861	0.075
1.043	0.066
1.399	0.067
1.476	0.073
1.601	0.081
1.734	0.070
1.938	0.074
1.996	0.071
2.082	0.071
2.193	0.061
2.269	0.061
2.396	0.065
2.561	0.066
2.628	0.062
2.672	0.058
2.689	0.051

c. Angular Spectral Reflectance (Wavelength Dependence)

Only Grim, Linfored, Dillow, Spinak, and Mills [A00001] have measured the angular spectral reflectance for a 290 mil thick disk of Plexiglas in the 2-15 μm region with the incident angle of 15° and 45°, as shown in Table 16-6 and Figure 16-5. The reflectance values increase slightly with the increasing of incident angle. The provisional values are for Plexiglas at 293 K and are listed in Table 16-5 and shown in Figure 16-4. The estimated uncertainty is about $\pm 30\%$.

TABLE 16-5. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF LUCTIE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ	λ	ρ	λ	ρ
PLEXIGLAS θ=15° T = 293		PLEXIGLAS θ=15° T = 293 (CONT.)		PLEXIGLAS θ=15° T = 293 (CONT.)	
0.24	0.081	3.25	0.030	14.3	0.037
0.39	0.082	3.41	0.035	15.0	0.037
0.51	0.079	3.54	0.032		
0.80	0.075	3.68	0.036		
0.94	0.072	3.80	0.030		
1.00	0.070	3.84	0.029		
1.08	0.070	3.95	0.033		
1.19	0.063	4.00	0.032		
1.27	0.059	4.16	0.033		
1.33	0.060	4.68	0.032		
1.46	0.067	4.78	0.028		
1.54	0.073	5.00	0.029		
1.60	0.069	5.29	0.026		
1.65	0.047	5.62	0.022		
1.79	0.061	5.78	0.039		
1.82	0.060	6.00	0.032		
1.89	0.049	6.50	0.022		
1.96	0.050	6.75	0.026		
2.00	0.047	7.00	0.030		
2.13	0.048	7.30	0.027		
2.20	0.050	7.50	0.023		
2.48	0.036	7.75	0.025		
2.53	0.035	8.00	0.027		
2.58	0.028	8.50	0.038		
2.63	0.022	8.75	0.043		
2.66	0.036	9.00	0.036		
2.69	0.030	9.50	0.033		
2.70	0.038	9.73	0.031		
2.73	0.029	10.00	0.033		
2.76	0.025	10.50	0.031		
2.80	0.035	11.0	0.033		
2.84	0.029	11.8	0.029		
2.90	0.038	12.0	0.032		
2.96	0.026	12.4	0.035		
3.00	0.036	12.7	0.033		
3.07	0.026	13.0	0.032		
3.12	0.037	13.5	0.030		
3.17	0.033	13.6	0.030		
3.20	0.034	14.0	0.033		

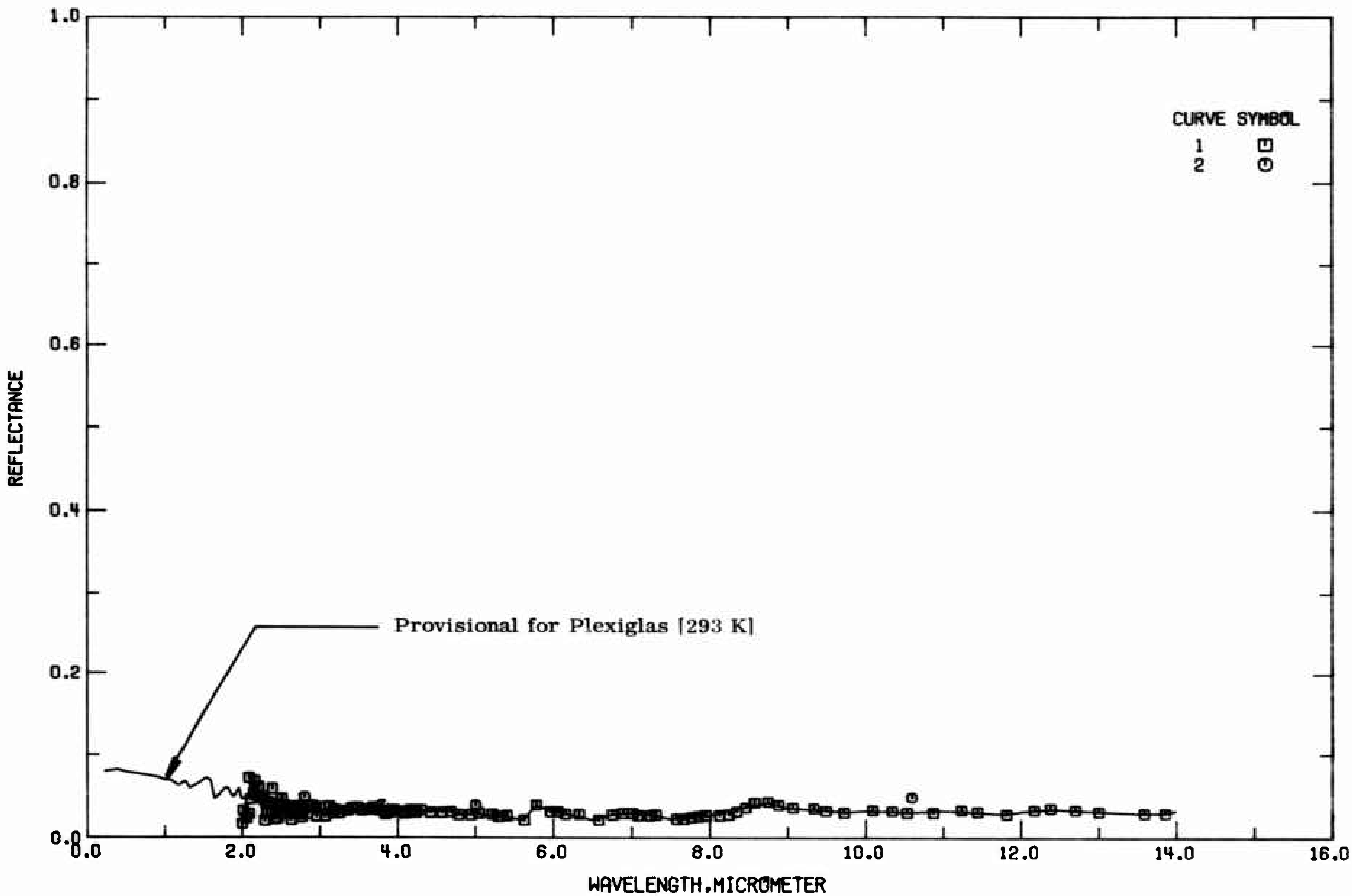


FIGURE 16-4. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF LUCITE (WAVELENGTH DEPENDENCE).

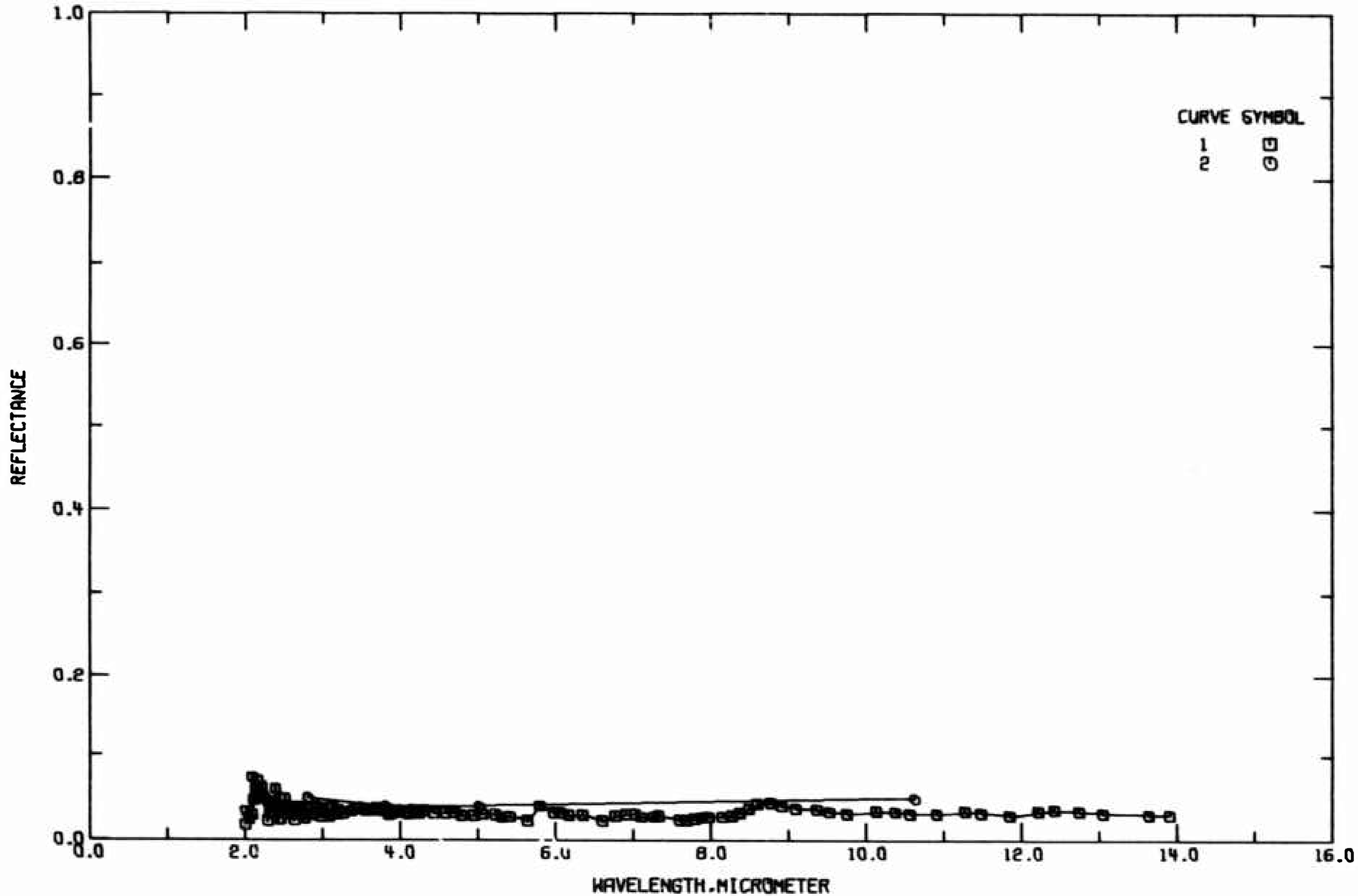


FIGURE 16-5. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF LUCITE (WAVELENGTH DEPENDENCE).

TABLE 16-6. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF LUCITE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1		Grimm, T.C., Linford, R.M.F., Dillow, C.F., Spinak, S., and Mills, J.P.	1972	2-15	293	Plexiglas 55 Sample M-1	Spectral hemispherical reflectance was measured by utilizing a Dune Associate ellipsoidal-mirror reflectometer; one in. diameter disc sample was used; data were extracted from the smooth curve; θ=15°, ω'=2π.
2		Grimm, T.C., et al.	1972	2-15	293	Plexiglas 55 Sample M-1	The above specimen except the incident angle θ=45° and data were extracted from the table.

TABLE 16-7. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF LUCITE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ	λ	ρ	λ	ρ	λ	ρ
CURVE 1		CURVE	1(CONT.)	CURVE	1(CONT.)	CURVE	2(CONT.)
T = 293.							
		3.12	0.038	7.08	0.027	3.8	0.04
2.00	0.017	3.17	0.030	7.24	0.027	5.0	0.04
2.01	0.033	3.20	0.034	7.31	0.028	10.6	0.05
2.05	0.024	3.25	0.030	7.58	0.023		
2.09	0.073	3.36	0.033	7.67	0.023		
2.09	0.029	3.41	0.036	7.77	0.025		
2.11	0.047	3.48	0.037	7.86	0.026		
2.15	0.054	3.54	0.033	7.95	0.027		
2.16	0.059	3.63	0.034	8.13	0.027		
2.19	0.051	3.68	0.037	8.25	0.028		
2.21	0.062	3.73	0.034	8.35	0.032		
2.24	0.050	3.78	0.033	8.47	0.037		
2.27	0.047	3.84	0.029	8.58	0.043		
2.29	0.021	3.88	0.031	8.75	0.044		
2.30	0.043	3.95	0.034	8.89	0.040		
2.32	0.030	3.98	0.032	9.07	0.037		
2.34	0.043	4.04	0.032	9.34	0.036		
2.37	0.031	4.09	0.030	9.50	0.033		
2.39	0.060	4.16	0.034	9.73	0.031		
2.43	0.023	4.23	0.031	10.10	0.034		
2.45	0.039	4.30	0.034	10.35	0.033		
2.45	0.024	4.42	0.031	10.54	0.031		
2.47	0.040	4.57	0.031	10.88	0.031		
2.49	0.035	4.68	0.032	11.24	0.034		
2.51	0.048	4.78	0.028	11.45	0.032		
2.53	0.036	4.94	0.028	11.82	0.029		
2.55	0.039	5.04	0.030	12.18	0.034		
2.57	0.029	5.21	0.029	12.39	0.036		
2.63	0.022	5.29	0.026	12.71	0.034		
2.66	0.037	5.40	0.027	13.01	0.032		
2.69	0.030	5.62	0.022	13.60	0.030		
2.70	0.038	5.78	0.040	13.87	0.030		
2.73	0.029	5.96	0.032	14.02	0.033		
2.76	0.025	6.05	0.032	14.29	0.037		
2.79	0.036	6.15	0.029	14.67	0.037		
2.84	0.029	6.33	0.029				
2.90	0.039	6.58	0.022	CURVE 2			
2.96	0.026	6.75	0.028	T = 293.			
3.00	0.037	6.89	0.030				
3.07	0.026	7.01	0.030	2.8	0.05		

d. Normal Spectral Absorptance (Wavelength Dependence)

Byrne and Mancinelli [T32388] measured the absorptance of a 3.2 mm thick specimen in the 0.2 to 2.7 μm region. Pilipetskii, Raizer, and Upadyshov [E37991] used a ruby laser $\lambda = 0.69$ μm with incident power of 0.5-1.1 joules to obtain the absorptance for specimens 43 mm long. According to Eq. (4.16-5), $\alpha(\lambda) \cong (1-R)\ [1 - (1-R)e^{-ad} - Re^{-2ad}]$ which is strongly dependent on the thickness of thin films. However, for the bulk materials in the wavelength region $\lambda > 3$ μm

$$\alpha(\lambda) \approx (1-R) \qquad (4.16\text{-}9)$$

which is independent of the thickness, and the material becomes opaque. From Kirchhoff's law $\alpha(\lambda) = \epsilon(\lambda)$, the absorptance is equal to emittance. The calculated values are shown in Table 16-8 and in Figure 16-6 together with the experimental results.

The estimated uncertainty is about ±20%.

TABLE 16-6. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF LUCITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α
THICKNESS 3.2MM		THICKNESS 3.2MM		THICKNESS 3.2MM	
T = 293		T = 293 (CONT.)		T = 293 (CONT.)	
0.240	0.919	1.92	0.430	9.00	0.964
0.259	0.901	1.95	0.400	9.50	0.967
0.290	0.910	2.00	0.371	10.00	0.957
0.350	0.910	2.09	0.699	10.50	0.969
0.364	0.902	2.13	0.811	11.00	0.967
0.369	0.690	2.20	0.950	11.80	0.971
0.374	0.350	2.48	0.964	12.00	0.968
0.376	0.772	2.53	0.961	12.70	0.977
0.389	0.145	2.58	0.926	13.00	0.968
0.396	0.100	2.63	0.927	13.50	0.970
0.403	0.040	2.66	0.922	14.00	0.967
0.422	0.012	2.80	0.965	14.50	0.963
0.510	0.012	3.00	0.964	15.00	0.963
0.700	0.012	3.07	0.974		
0.741	0.009	3.12	0.963		
0.763	0.007	3.20	0.966		
0.788	0.007	3.25	0.970		
0.815	0.005	3.41	0.965		
0.844	0.020	3.54	0.968		
0.890	0.056	3.65	0.964		
1.000	0.034	3.80	0.970		
1.181	0.253	3.84	0.971		
1.214	0.111	3.95	0.967		
1.270	0.039	4.22	0.966		
1.318	0.074	4.45	0.957		
1.347	0.250	4.68	0.968		
1.367	0.311	4.78	0.972		
1.400	0.258	5.00	0.971		
1.500	0.081	5.29	0.974		
1.607	0.148	5.62	0.978		
1.662	0.600	5.78	0.961		
1.677	0.845	6.00	0.968		
1.709	0.778	6.50	0.978		
1.727	0.732	6.75	0.972		
1.764	0.510	7.00	0.970		
1.826	0.340	7.50	0.977		
1.877	0.365	8.00	0.973		
1.890	0.617	8.50	0.962		
1.900	0.700	8.75	0.957		

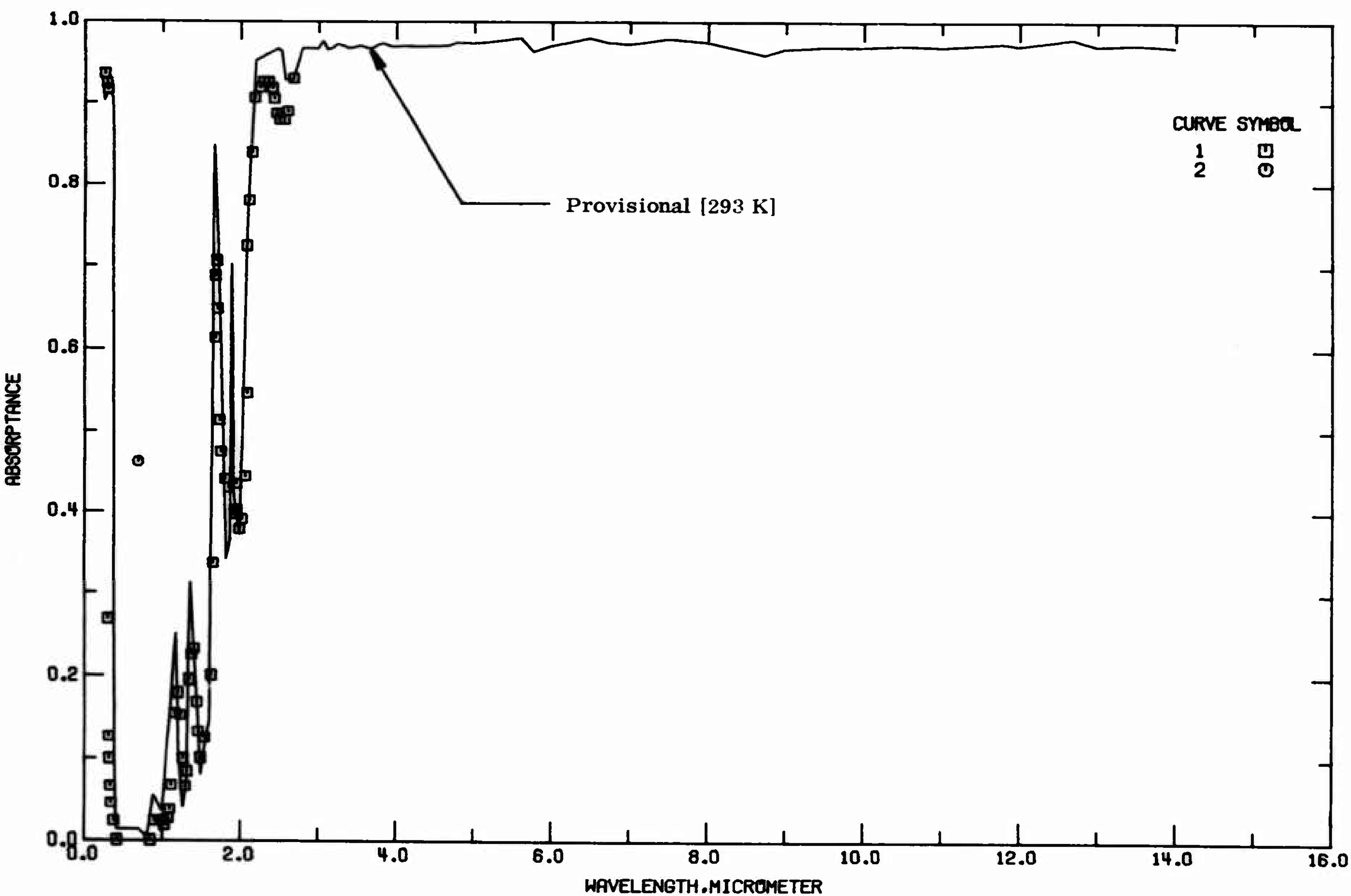


FIGURE 16-6. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF LUCITE (WAVELENGTH DEPENDENCE).

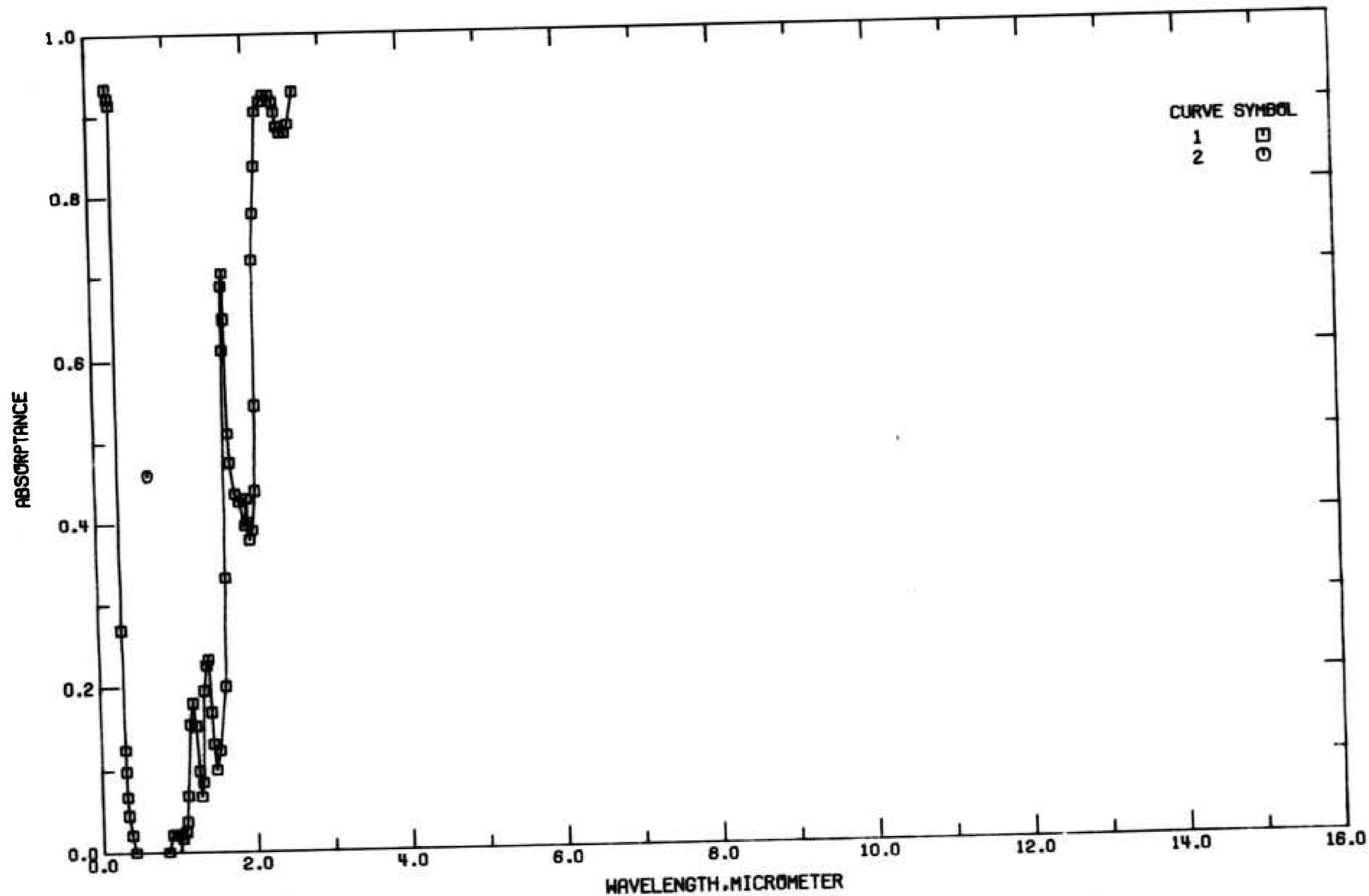


FIGURE 16-7. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF LUCITE (WAVELENGTH DEPENDENCE).

TABLE 16-9. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF LUCITE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T32388	Byrne, R. T. and Mancinelli, L. N.	1954	0.2-2.7	~293	Lucite	Approx. 1/8 in. thick specimen; Beckman Spectrometer, General Electric Spectrometer and Perkin-Elmer Spectrometer were employed; data were extracted from the smooth curve; $\theta \sim 0°$, reported error 5%.
2	E37991	Pilipetskii, N. F., Raizer, Yu. P., and Upadyshev, V. A.	1968	0.69	~293	PMA	Polymethylmeth acrylate sample of dimension 43 x 9 x 9 mm; ruby laser with incident power about 0.5-1.1 Joules was used; $\theta \sim 0°$, reported error 9%.

TABLE 16-10. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF LUCITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α
CURVE 1		CURVE 1 (CONT.)	
T = 293.			
0.260	0.934	1.860	0.428
0.285	0.922	1.930	0.396
0.296	0.914	1.956	0.433
0.298	0.270	1.956	0.401
0.309	0.126	1.992	0.378
0.316	0.099	2.024	0.390
3.326	0.067	2.069	0.442
0.337	0.045	2.094	0.545
0.375	0.022	2.094	0.721
0.418	0.000	2.123	0.777
0.843	0.009	2.157	0.837
0.899	0.022	2.182	0.904
0.959	0.022	2.252	0.917
1.027	0.017	2.298	0.924
1.073	0.025	2.362	0.924
1.098	0.037	2.408	0.916
1.112	0.068	2.431	0.903
1.156	0.156	2.464	0.884
1.196	0.181	2.504	0.876
1.230	0.154	2.564	0.876
1.264	0.099	2.608	0.887
1.290	0.067	2.682	0.928
1.315	0.085	CURVE 2	
1.345	0.195	T = 293.	
1.378	0.225	0.69	0.46
1.408	0.233		
1.441	0.170		
1.456	0.132		
1.491	0.100		
1.539	0.124		
1.628	0.200		
1.657	0.335		
1.682	0.612		
1.688	0.687		
1.705	0.704		
1.712	0.648		
1.737	0.512		
1.755	0.473		
1.811	0.439		

e. Normal Spectral Transmittance (Wavelength Dependence)

There are 20 sets of experimental data available for the transmittance of Lucite as listed in Table 16-13. Of these, 12 sets measured on thin film samples are shown in Figure 16-10. They represent reasonably consistent results with each other. Major absorption peaks near $\lambda = 3.4$, 5.8, 6.9, 7.2, 8.0, 8.7, and 13.4 μm are observed.

As we have mentioned in d., the bulk Lucite materials become opaque above $\lambda = 3\ \mu m$. At the visible and near infrared region it transmits about 90%. According to Eq. (4.16-6), $\tau(\lambda) = (1-R)^2 e^{-ad}$, the transmittance becomes very strongly dependent on the thickness of the sample where absorption coefficient a is not small. Therefore, the provisional values of transmittance for a sample with thickness of 3.2 mm at 293 K are derived, based on the works of Byrne and Mancinelli [T32388], Acitelli, Gumby, and Naujobas [T40338], Turner and Keller [T77381], and duPont Co. [E62601]. The values are shown in Table 16-11 and in Figure 16-8 with the experimental data.

The provisional values are estimated with an uncertainty of about ±30%.

TABLE 16-11. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ	λ	τ	λ	τ
THICKNESS 3.2MM		THICKNESS 3.2MM		THICKNESS 3.2MM	
T = 293		T = 293 (CONT.)		T = 293 (CONT.)	
0.250	0.000	1.828	0.600	11.50	0.00
0.259	0.013	1.877	0.585	12.00	0.00
0.261	0.041	1.886	0.333	12.50	0.00
0.262	0.018	1.899	0.253	13.00	0.00
0.264	0.010	1.309	0.271	13.50	0.00
0.268	0.000	1.909	0.319	14.00	0.00
0.357	0.000	1.914	0.339	14.50	0.00
0.364	0.015	1.916	0.456	15.00	0.00
0.369	0.030	1.924	0.470		
0.374	0.069	1.928	0.502		
0.376	0.146	1.950	0.444		
0.389	0.775	2.00	0.582		
0.398	0.817	2.09	0.251		
0.403	0.880	2.13	0.141		
0.422	0.903	2.20	0.000		
0.510	0.908	2.48	0.000		
0.700	0.912	2.53	0.003		
0.741	0.916	2.58	0.046		
0.765	0.918	2.61	0.060		
0.788	0.918	2.63	0.051		
0.815	0.923	2.65	0.042		
0.844	0.922	2.80	0.000		
0.895	0.874	3.00	0.003		
1.000	0.396	3.80	0.001		
1.181	0.584	4.00	0.005		
1.214	0.325	4.50	0.004		
1.259	0.392	5.00	0.00		
1.318	0.866	5.50	0.00		
1.347	0.592	6.00	0.00		
1.367	0.629	6.50	0.00		
1.400	0.679	7.00	0.00		
1.500	0.849	7.50	0.00		
1.607	0.783	8.00	0.00		
1.662	0.355	8.50	0.00		
1.670	0.134	9.00	0.00		
1.677	0.104	9.50	0.00		
1.709	0.170	10.00	0.00		
1.727	0.209	10.50	0.00		
1.784	0.429	11.00	0.00		

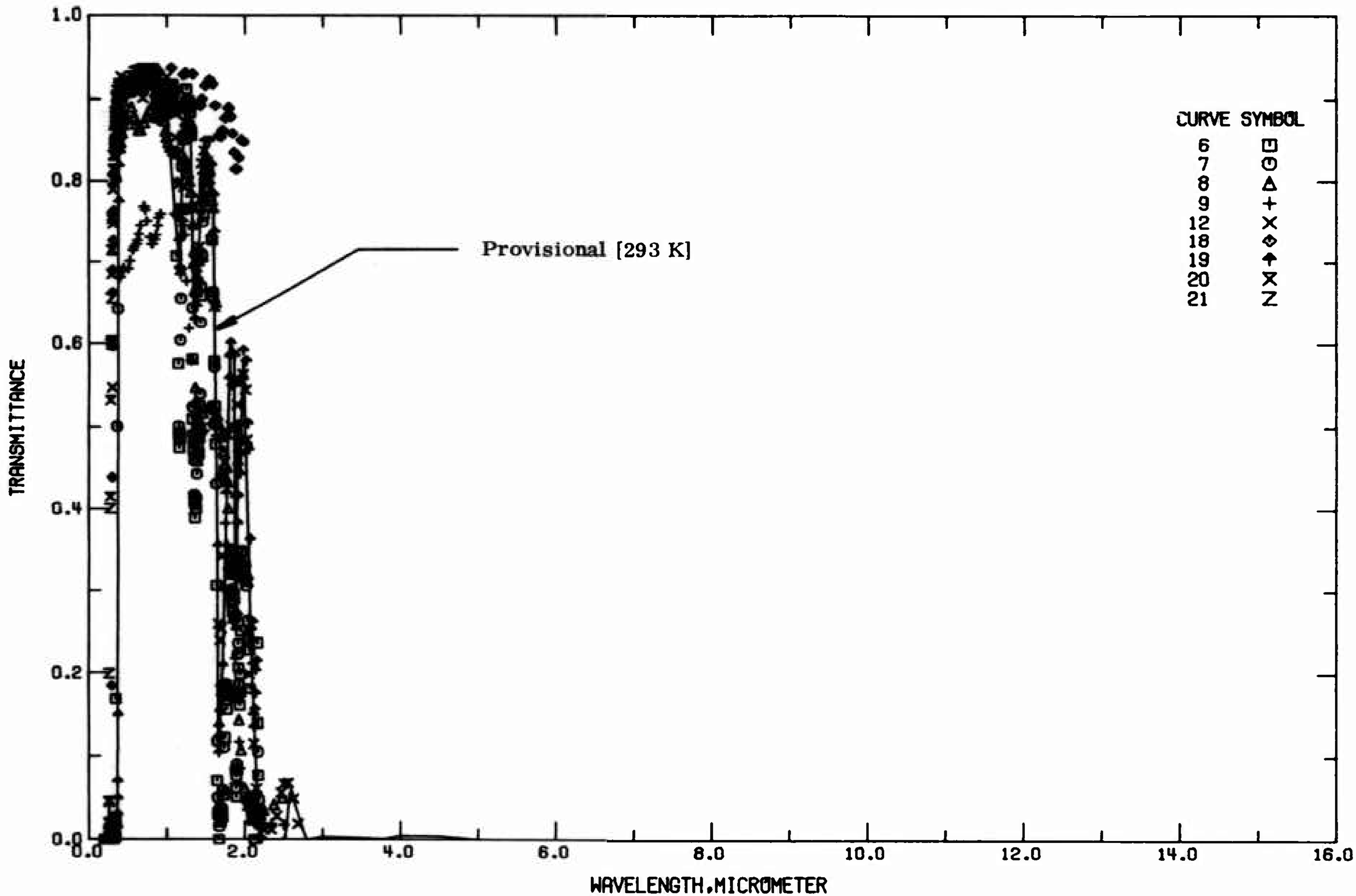


FIGURE 16-8. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE).

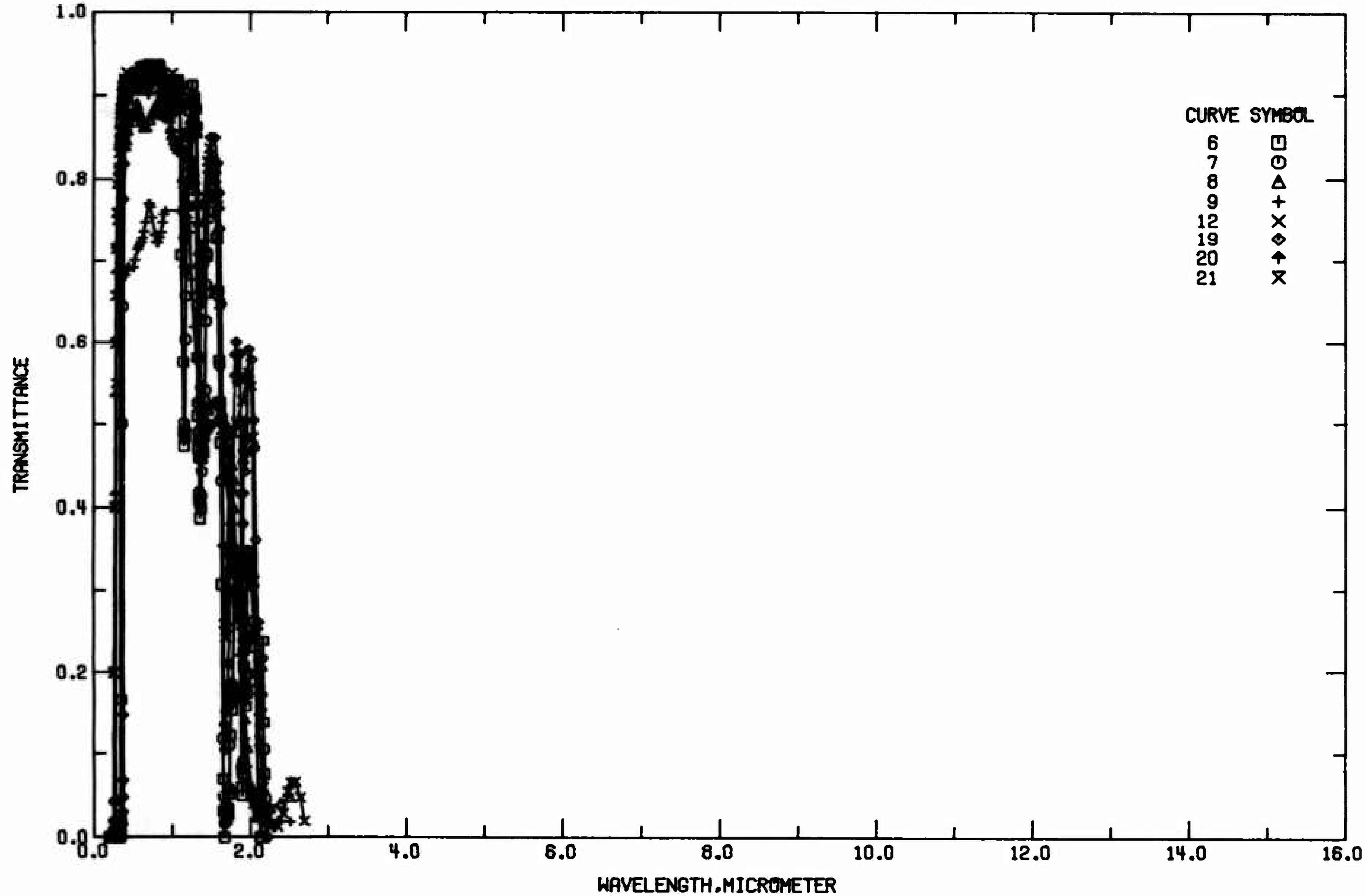


FIGURE 16-9. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE).

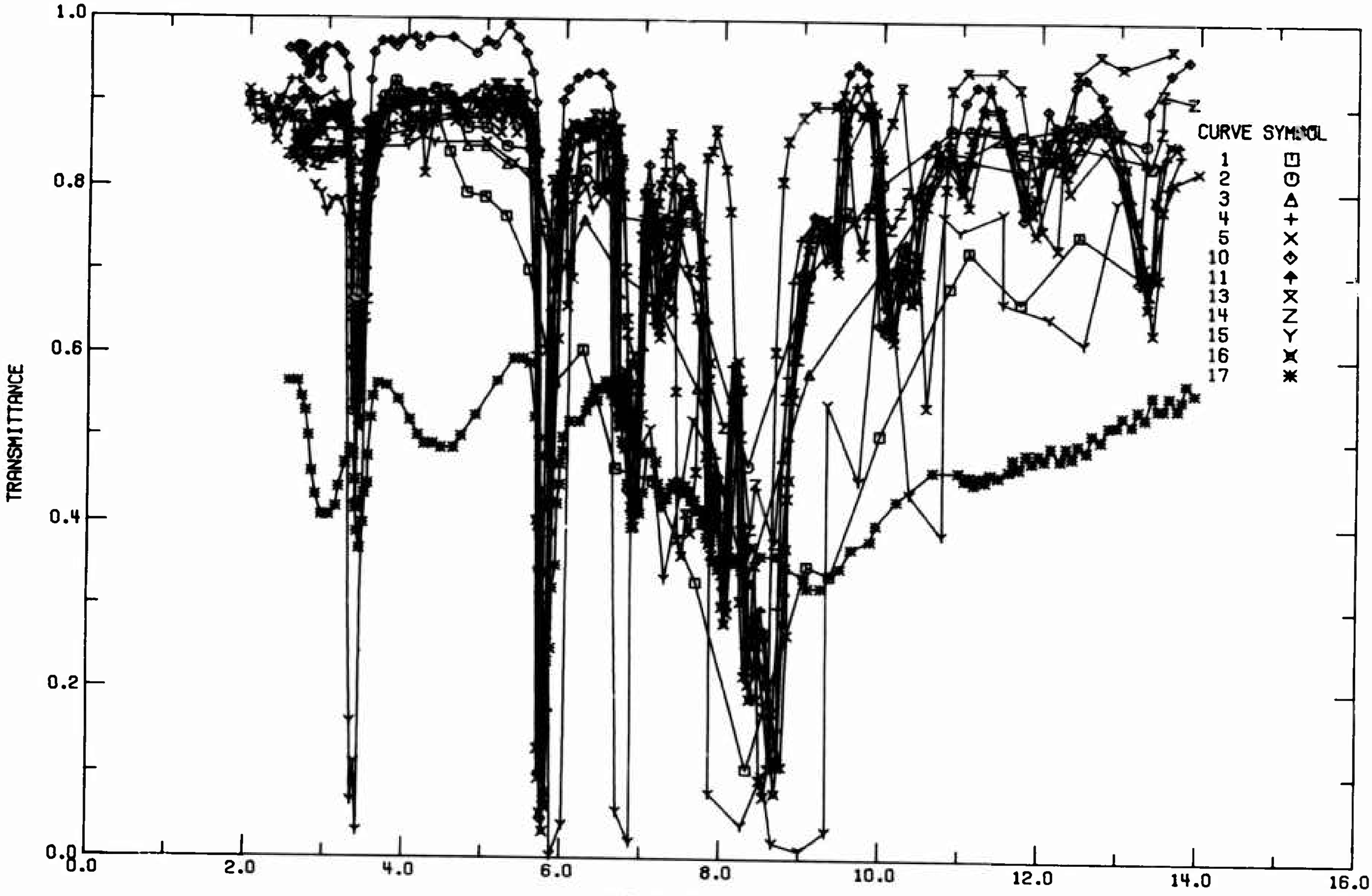


FIGURE 16-10. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE THIN FILMS (WAVELENGTH DEPENDENCE).

TABLE 16-12. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T40581	Wells, A.J.	1940	3.3-25	293	Lucite	Films were made from the powder of DuPont Co. by mercury and dip method; film thickness 25 μ; data were extracted from the figure; $\theta\sim0°$.
2	T40581	Wells, A.J.	1940	3.3-25	293	Plexiglas	5 μ thickness sheet was obtained from the Röme and Haas Co.; films were made by mercury method; data were extracted from the figure; $\theta\sim0°$.
3	T40581	Wells, A.J.	1940	3.3-25	293	Plexiglas	The above specimen except 7 μ thickness.
4	T24947	Armour Research Foundation	1961	2-15	293	Lucite	0.01 in. thickness sample was deposited on the surface of sodium chloride discs, it transmit well in the 2-6 μ and 9.5-15 μ spectral region; in the visible region, its refractive index is 1.49; curing temperature = 54 C; data were extracted from the figure; $\theta\sim0°$.
5	T19814	Moore, L.E., Prastein, M., Tompkins, E.H., and VanOsterburg, D.O.	1958	2-15	293	Lucite	Refractive index = 1.49 at λ = 5893 Å; unknown thickness; data were extracted from the figure; $\theta\sim0°$.
6	T40338	Acitelli, M.A., Gumby, W.L., and Naujokas, A.A.	1966	0.3-2.2	296	Poly(methyl methacrylate)	7.46 mm thickness disc about 50 mm in diameter; Cary Spectrophotometer model 14 was employed; data were extracted from the figure; $\theta\sim0°$.
7	T40338	Acitelli, M.A., et al.	1966	0.3-2.2	296	Poly(methyl methacrylate)	The above specimen after 100 standard fade hr in solarization.
8	T47094	Holland, W.R.	1967	0.2-2.6	296	Cross linked methacrylate	1/4 in. thick; the transmittance was measured by using a Perkin-Elmer model 99 mono-chrometer; data were extracted from the figure; $\theta\sim0°$.
9	T47094	Holland, W.R.	1967	0.2-2.6	296	Cross linked methacrylate	The above specimen except it was indicated by simulated sunlight for 14 days, 30 days, 60 days and 90 days respectively.
10	T76795	Stimler, S.S. and Kaganise, R.E.	1966	2.5-25	~293	Lucite 763497	A Beckman model IR-12 spectrophotometer was used to obtain the spectra of film sample; specimen was obtained from DuPont; data were extracted from the figure; $\theta\sim0°$.
11	T51594	Story, J.G.	1961	2-15	296	Polymethyl methacrylate	No thickness has been given; the absorption peak at 3.37 μ indicating absence of long chains of CH_2 groups; strong absorption at 5.77 μ due to the C-O bond and strong absorption at 8 to 9 μ region, probably due to C-O-C stretching made; data were extracted from the figure.
12	T32388	Byrne, R.F. and Mancinelli, L.N.	1954	0.2-2.7	293	Lucite	Approx. 1/8 in. thick; for the ultraviolet region Beckman Model DC Spectrometer was used; for the visible and near infrared region a General Electric Recording Spectrometer was used; for the measurement above 1 μm, a Perkin-Elmer Infrared Spectrometer was employed; data were extracted from the figure.
13	T76798	Lara, M.O.	1967	2.5-25	~293	Lucite	The specimen was condensed pyrolyzate on potassium bromide or sodium chloride; a Beckman IR-9 double beamed, prism-grating infrared spectrophotometer was used to obtain the spectra; data were extracted from the figure; $\theta\sim0°$.
14	T76798	Lara, M.O.	1967	2.5-25	~293	Plexiglass	Similar to the above specimen.
15	T35117	Hass, M. and O'Hara, M.	1965	2.86-100	~293	DP Polymethyl methacrylate grating	0.051 μm thickness specimen was obtained from diffraction products; a Perkin-Elmer model and a Cary Spectrometer were used for measurements; data were extracted from the figure; $\theta\sim0°$.

TABLE 16-12. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
16	T76812	Kagarise, R.E. and Weinberger, L.A.	1954	2-15	~293	Plexiglas B	The specimen was obtained from Rohm and Haas Co.; the specimen was dissolved in methylethyl ketone and the resulting viscous solution spread uniformly over a rock salt or KBr plate, the solvent was removed by heating under vacuum or normal evaporation at room temperature; a Perkin-Elmer model 21 spectrometer was used; data were extracted from the figure; $\theta\sim0°$.
17	E26638	Carbajal, B.G., III.	1966	2.5-25	~293	GDP MMA	Glow discharge polymerized methylmethacrylate; data were extracted from the smooth curve.
18	T77381	Turner, H.C. and Keller, E.E.	1959	0.185-2.0	~293	Plexiglas	Beckman DK-2 spectroreflectometer was used for measurement; data were extracted from the figure; $\theta\sim0°$.
19	E62501	du Pont Co.	1968	0.20-2.30	~293	Lucite 129, 130, 140, 147, 148	3.2 mm thickness; index of refraction = 1.491; dispersion = 54; data were extracted from the figure.
20	E62601	du Pont Co.	1968	0.2-0.7	~293	Lucite 140 T	3.2 mm thickness; data were extracted from the figure.
21	E16981	Imperial Chemical Industries, Ltd.	1962	0.25-0.7	~293	"Daikon" MG	0.125 in. thickness; disc specimen; data were extracted from the figure.

TABLE 16-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 1	
T = 293.	
3.35	0.762
3.45	0.751
3.57	0.802
3.70	0.857
3.85	0.914
4.00	0.880
4.17	0.880
4.35	0.889
4.55	0.341
4.76	0.792
5.00	0.787
5.26	0.765
5.56	0.700
5.88	0.564
6.25	0.605
6.67	0.464
7.14	0.450
7.69	0.328
8.33	0.105
9.09	0.348
9.38	0.336
10.00	0.503
10.87	0.682
11.11	0.724
11.76	0.663
12.50	0.745
13.33	0.692
14.29	0.686
15.38	0.835
16.67	0.844
18.18	0.835
20.00	0.799
22.22	0.858
25.00	0.848
CURVE 2	
T = 293.	
3.35	0.862
CURVE 2 (CONT.)	
3.45	0.862
3.57	0.865
3.70	0.904
3.85	0.923
4.00	0.907
4.17	0.907
4.35	0.914
4.55	0.904
4.76	0.870
5.00	0.870
5.26	0.849
5.56	0.846
5.88	0.728
6.25	0.821
6.57	0.766
7.14	0.760
7.63	0.671
8.33	0.468
9.09	0.697
10.00	0.806
10.87	0.871
11.11	0.871
11.76	0.865
12.50	0.879
13.33	0.856
14.29	0.851
15.38	0.890
16.67	0.879
18.18	0.879
20.00	0.870
22.22	0.922
25.00	0.918
CURVE 3	
T = 293.	
3.35	0.830
3.45	0.830
3.57	0.844
3.70	0.888
CURVE 3 (CONT.)	
3.85	0.896
4.00	0.907
4.17	0.907
4.35	0.914
4.55	0.904
4.76	0.849
5.00	0.849
5.26	0.827
5.56	0.820
5.88	0.680
6.25	0.762
6.67	0.700
7.14	0.667
7.69	0.560
8.33	0.332
9.09	0.579
10.00	0.702
10.87	0.835
11.11	0.835
11.76	0.823
12.50	0.853
13.33	0.835
14.29	0.840
15.38	0.863
16.67	0.863
18.18	0.861
20.00	0.835
22.22	0.891
25.00	0.871
CURVE 4	
T = 293.	
2.00	0.906
2.14	0.905
2.20	0.889
2.36	0.889
2.52	0.923
2.62	0.923
2.85	0.899
CURVE 4 (CONT.)	
3.06	0.908
3.21	0.878
3.28	0.752
3.33	0.680
3.36	0.532
3.43	0.622
3.47	0.723
3.53	0.806
3.60	0.868
3.78	0.895
4.20	0.895
4.41	0.907
4.58	0.898
4.96	0.918
5.07	0.901
5.43	0.889
5.54	0.847
5.65	0.602
5.70	0.346
5.74	0.097
5.81	0.286
5.83	0.651
5.93	0.703
5.93	0.832
6.08	0.868
6.29	0.860
6.42	0.868
6.47	0.888
6.56	0.888
6.61	0.817
6.64	0.572
6.74	0.572
6.86	0.446
6.94	0.520
6.97	0.747
7.02	0.793
7.09	0.695
7.13	0.636
7.23	0.686
7.31	0.673
CURVE 4 (CONT.)	
7.46	0.799
7.57	0.799
7.78	0.693
7.84	0.575
7.84	0.403
7.93	0.478
8.02	0.349
8.13	0.588
8.25	0.398
8.33	0.228
8.43	0.289
8.56	0.172
8.62	0.111
8.73	0.153
8.73	0.299
8.77	0.474
8.83	0.575
8.89	0.689
8.98	0.739
9.17	0.765
9.30	0.713
9.42	0.743
9.44	0.838
9.52	0.888
9.66	0.921
9.83	0.890
9.95	0.783
10.00	0.683
10.04	0.658
10.12	0.681
10.22	0.731
10.32	0.690
10.43	0.792
10.70	0.843
10.98	0.805
11.36	0.923
11.78	0.779
11.91	0.779
12.18	0.877
12.34	0.814
CURVE 4 (CONT.)	
12.74	0.878
12.85	0.878
13.36	0.665
13.61	0.805
13.77	0.843
14.10	0.843
14.24	0.810
14.65	0.810
14.77	0.797
14.96	0.810
CURVE 5	
T = 293.	
2.00	0.911
2.09	0.876
2.24	0.876
2.34	0.854
2.47	0.881
2.70	0.906
2.86	0.867
3.25	0.867
3.32	0.784
3.36	0.587
3.42	0.508
3.48	0.640
3.53	0.798
3.63	0.840
3.79	0.872
4.96	0.883
5.18	0.865
5.26	0.889
5.38	0.865
5.46	0.877
5.57	0.848
5.65	0.801
5.71	0.400
5.80	0.064
5.86	0.389
5.93	0.618

TABLE 16-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE	5 (CONT.)	CURVE	5 (CONT.)	CURVE	6 (CONT.)	CURVE	6 (CONT.)	CURVE	6 (CONT.)	CURVE	6 (CONT.)
5.97	0.755	9.21	0.742	0.349	0.841	1.202	0.766	1.696	0.022	2.177	0.137
6.02	0.815	9.32	0.742	0.355	0.868	1.207	0.817	1.705	0.027	2.185	0.076
6.12	0.855	9.46	0.699	0.368	0.885	1.216	0.850	1.717	0.027	2.200	0.019
6.25	0.838	9.53	0.768	0.384	0.899	1.234	0.881	1.733	0.052		
6.47	0.848	9.56	0.845	0.415	0.909	1.253	0.895	1.749	0.121	CURVE 7	
6.54	0.863	9.85	0.899	0.537	0.911	1.261	0.911	1.759	0.170	T = 296.	
6.69	0.815	10.00	0.838	0.544	0.908	1.268	0.889	1.766	0.170		
6.71	0.639	10.08	0.665	0.554	0.911	1.277	0.896	1.775	0.153	0.200	0.000
6.71	0.515	10.17	0.617	0.628	0.911	1.291	0.896	1.782	0.169	0.336	0.000
6.84	0.329	10.33	0.722	0.696	0.919	1.308	0.883	1.810	0.320	0.345	0.018
6.94	0.426	10.45	0.668	0.734	0.919	1.318	0.855	1.819	0.330	0.364	0.500
6.99	0.527	10.57	0.781	0.748	0.925	1.335	0.580	1.831	0.330	0.376	0.642
7.02	0.654	10.77	0.830	0.772	0.925	1.338	0.509	1.840	0.321	0.399	0.854
7.10	0.757	10.96	0.830	0.793	0.933	1.348	0.474	1.847	0.288	0.410	0.878
7.16	0.738	11.10	0.780	0.832	0.935	1.354	0.462	1.856	0.274	0.426	0.894
7.16	0.656	11.30	0.873	0.851	0.927	1.359	0.408	1.866	0.295	0.456	0.905
7.21	0.620	11.54	0.873	0.864	0.917	1.366	0.388	1.876	0.267	0.538	0.909
7.29	0.663	11.82	0.775	0.876	0.899	1.374	0.405	1.893	0.061	0.549	0.907
7.37	0.649	11.95	0.746	0.886	0.877	1.383	0.400	1.899	0.050	0.558	0.915
7.48	0.760	12.23	0.846	0.893	0.877	1.393	0.460	1.908	0.083	0.685	0.919
7.64	0.760	12.37	0.799	0.904	0.895	1.401	0.475	1.918	0.167	0.768	0.926
7.77	0.714	12.81	0.850	0.925	0.916	1.412	0.468	1.927	0.206	0.813	0.933
7.85	0.592	13.05	0.811	0.940	0.916	1.420	0.487	1.934	0.184	0.838	0.933
7.88	0.363	13.32	0.710	0.948	0.913	1.449	0.658	1.942	0.158	0.859	0.926
7.98	0.441	13.43	0.629	0.962	0.913	1.462	0.705	1.950	0.174	0.873	0.912
8.01	0.338	13.50	0.696	0.970	0.899	1.481	0.760	1.957	0.251	0.883	0.893
8.08	0.293	13.55	0.778	0.986	0.895	1.496	0.790	1.968	0.317	0.889	0.880
8.23	0.557	13.69	0.810	0.999	0.882	1.514	0.816	1.982	0.330	0.898	0.880
8.30	0.381	14.00	0.823	1.012	0.895	1.533	0.816	1.992	0.330	0.911	0.905
8.35	0.327	14.47	0.803	1.026	0.895	1.562	0.781	2.004	0.318	0.924	0.916
8.35	0.206	15.00	0.766	1.050	0.911	1.587	0.726	2.020	0.314	0.964	0.916
8.45	0.188			1.063	0.916	1.601	0.658	2.051	0.244	0.974	0.901
8.51	0.271	CURVE 6		1.079	0.916	1.614	0.577	2.065	0.228	0.984	0.901
8.57	0.271	T = 296.		1.094	0.909	1.625	0.524	2.077	0.179	0.993	0.888
8.65	0.173			1.104	0.889	1.635	0.479	2.106	0.024	1.004	0.888
8.77	0.109	0.200	0.000	1.130	0.706	1.645	0.306	2.118	0.024	1.015	0.895
8.84	0.267	0.325	0.000	1.151	0.575	1.653	0.070	2.132	0.000	1.029	0.895
8.84	0.431	0.339	0.005	1.160	0.490	1.660	0.031	2.152	0.024	1.053	0.915
8.89	0.546	0.344	0.026	1.165	0.475	1.673	0.000	2.171	0.023	1.074	0.915
9.01	0.659	0.349	0.166	1.173	0.486	1.685	0.026	2.171	0.237	1.090	0.905

TABLE 16-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE	7(CONT.)
1.102	0.884
1.114	0.833
1.160	0.500
1.166	0.485
1.173	0.492
1.181	0.603
1.186	0.655
1.205	0.816
1.215	0.856
1.238	0.889
1.259	0.911
1.265	0.890
1.274	0.896
1.236	0.895
1.305	0.883
1.318	0.861
1.333	0.643
1.338	0.523
1.343	0.498
1.355	0.481
1.357	0.418
1.364	0.405
1.373	0.414
1.383	0.414
1.308	0.444
1.394	0.490
1.402	0.499
1.413	0.490
1.419	0.499
1.424	0.527
1.434	0.539
1.441	0.625
1.447	0.670
1.457	0.708
1.467	0.750
1.478	0.775
1.493	0.799
1.509	0.821
1.529	0.821
1.541	0.813

λ	τ
CURVE	7(CONT.)
1.559	0.781
1.582	0.729
1.600	0.663
1.614	0.571
1.627	0.503
1.636	0.432
1.651	0.117
1.657	0.049
1.671	0.016
1.685	0.037
1.693	0.027
1.701	0.036
1.713	0.036
1.727	0.058
1.741	0.110
1.756	0.177
1.762	0.186
1.772	0.164
1.779	0.181
1.804	0.326
1.811	0.342
1.821	0.347
1.832	0.340
1.837	0.323
1.843	0.301
1.849	0.293
1.862	0.320
1.871	0.287
1.890	0.083
1.898	0.075
1.906	0.090
1.911	0.172
1.917	0.223
1.921	0.236
1.927	0.224
1.935	0.186
1.940	0.174
1.947	0.198
1.958	0.324
1.969	0.347

λ	τ
CURVE	7(CONT.)
1.978	0.349
2.006	0.332
2.026	0.305
2.046	0.263
2.064	0.240
2.096	0.048
2.102	0.032
2.116	0.032
2.129	0.000
2.141	0.028
2.148	0.034
2.164	0.034
2.179	0.020
2.181	0.105
2.190	0.047
2.200	0.027
CURVE 8	
T = 296.	
0.405	0.839
0.413	0.846
0.434	0.858
0.452	0.868
0.474	0.875
0.493	0.876
0.551	0.889
0.587	0.878
0.605	0.869
0.639	0.862
0.670	0.862
0.714	0.871
0.747	0.878
0.783	0.886
0.831	0.892
0.876	0.897
0.918	0.897
0.940	0.892
0.953	0.885
0.966	0.873

λ	τ
CURVE	8(CONT.)
0.982	0.861
0.999	0.853
1.019	0.846
1.046	0.840
1.082	0.835
1.125	0.832
1.213	0.830
1.239	0.824
1.260	0.816
1.279	0.808
1.295	0.799
1.313	0.786
1.326	0.771
1.341	0.746
1.355	0.712
1.362	0.665
1.369	0.547
1.373	0.529
1.383	0.518
1.406	0.511
1.469	0.516
1.539	0.523
1.592	0.523
1.620	0.520
1.644	0.514
1.679	0.502
1.706	0.488
1.730	0.471
1.750	0.456
1.765	0.439
1.791	0.400
1.932	0.141
1.959	0.107
2.004	0.061
2.028	0.049
2.061	0.041
2.111	0.035
2.247	0.035
2.383	0.041
2.494	0.049

λ	τ
CURVE 9	
T = 296.	
0.409	0.681
0.428	0.688
0.451	0.691
0.517	0.691
0.536	0.700
0.568	0.713
0.587	0.717
0.615	0.721
0.633	0.726
0.648	0.734
0.666	0.745
0.707	0.769
0.719	0.769
0.730	0.765
0.750	0.751
0.789	0.730
0.813	0.721
0.828	0.721
0.851	0.727
0.869	0.733
0.887	0.745
0.901	0.755
0.923	0.760
1.103	0.760
1.142	0.758
1.182	0.754
1.211	0.751
1.223	0.745
1.233	0.733
1.259	0.676
1.293	0.618
1.320	0.578
1.361	0.528
1.375	0.513
1.390	0.504
1.414	0.491
1.456	0.491
1.489	0.495
1.567	0.503

λ	τ
CURVE	9(CONT.)
1.605	0.503
1.623	0.500
1.641	0.489
1.691	0.443
1.758	0.382
1.782	0.356
1.827	0.302
1.858	0.261
1.883	0.218
1.905	0.176
1.936	0.116
1.949	0.085
1.963	0.064
1.994	0.045
2.038	0.035
2.104	0.029
2.188	0.023
2.348	0.019
2.506	0.018
CURVE 10	
T = 293.	
2.50	0.961
2.61	0.964
2.62	0.957
2.65	0.964
2.66	0.952
2.68	0.963
2.70	0.963
2.72	0.942
2.74	0.929
2.76	0.934
2.78	0.949
2.80	0.938
2.83	0.955
2.87	0.955
2.90	0.924
2.92	0.951
2.95	0.963

TABLE 16-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 10(CONT.)		CURVE 10(CONT.)		CURVE 10(CONT.)		CURVE 10(CONT.)		CURVE 11(CONT.)		CURVE 11(CONT.)	
3.11	0.963	6.14	0.928	9.15	0.768	17.79	0.951	5.74	0.197	8.42	0.218
3.18	0.955	6.27	0.934	9.26	0.750	18.59	0.951	5.78	0.072	8.45	0.267
3.25	0.939	6.45	0.934	9.35	0.718	19.08	0.915	5.83	0.174	8.51	0.296
3.28	0.895	6.55	0.918	9.40	0.754	19.84	0.908	5.85	0.429	8.60	0.211
3.33	0.529	6.61	0.886	9.47	0.897	20.45	0.857	5.89	0.563	8.72	0.119
3.35	0.667	6.64	0.854	9.57	0.936	20.83	0.893	5.94	0.703	8.81	0.315
3.38	0.424	6.69	0.527	9.69	0.947	21.74	0.906	5.98	0.800	8.84	0.498
3.40	0.608	6.72	0.516	9.79	0.938	22.78	0.893	6.02	0.846	8.90	0.611
3.43	0.659	6.78	0.559	9.87	0.892	23.81	0.836	6.12	0.574	8.97	0.696
3.46	0.813	6.80	0.523	9.98	0.636	25.00	0.776	6.25	0.850	9.09	0.737
3.48	0.876	6.81	0.440	10.06	0.627			6.50	0.877	9.18	0.761
3.52	0.833	6.87	0.416	10.15	0.703	CURVE 11		6.62	0.857	9.28	0.761
3.53	0.923	6.90	0.442	10.28	0.671	T = 296.		6.66	0.818	9.43	0.723
3.57	0.957	6.95	0.433	10.44	0.793			6.70	0.668	9.52	0.877
3.68	0.971	7.02	0.796	10.56	0.843	2.00	0.891	6.70	0.567	9.80	0.922
3.78	0.971	7.06	0.827	10.67	0.856	2.21	0.891	6.73	0.539	9.92	0.889
3.86	0.964	7.11	0.778	10.86	0.832	2.32	0.869	6.82	0.552	10.00	0.717
3.92	0.973	7.13	0.714	11.05	0.903	2.45	0.887	6.93	0.439	10.11	0.645
4.09	0.976	7.18	0.641	11.20	0.921	2.55	0.895	7.00	0.606	10.23	0.706
4.15	0.965	7.23	0.749	11.36	0.917	2.66	0.909	7.00	0.662	10.31	0.734
4.27	0.976	7.26	0.764	11.63	0.848	2.83	0.881	7.08	0.779	10.39	0.691
4.57	0.976	7.30	0.764	11.79	0.765	3.23	0.881	7.14	0.755	10.51	0.804
4.87	0.957	7.35	0.804	11.89	0.862	3.28	0.854	7.18	0.648	10.71	0.844
5.00	0.972	7.44	0.825	12.02	0.851	3.36	0.578	7.26	0.685	10.84	0.856
5.10	0.967	7.58	0.806	12.09	0.895	3.43	0.539	7.33	0.674	11.05	0.804
5.28	0.992	7.66	0.770	12.24	0.864	3.49	0.700	7.39	0.721	11.27	0.895
5.40	0.976	7.72	0.694	12.44	0.922	3.54	0.810	7.44	0.760	11.47	0.896
5.50	0.958	7.82	0.396	12.56	0.931	3.62	0.854	7.50	0.777	11.64	0.857
5.58	0.934	7.93	0.425	12.77	0.911	3.73	0.888	7.61	0.777	11.85	0.779
5.62	0.899	8.03	0.322	13.05	0.811	4.55	0.902	7.74	0.736	11.98	0.791
5.67	0.844	8.14	0.543	13.25	0.691	4.97	0.902	7.81	0.638	12.10	0.848
5.70	0.499	8.19	0.574	13.37	0.895	5.04	0.884	7.84	0.469	12.19	0.871
5.72	0.102	8.29	0.399	13.64	0.938	5.18	0.877	7.88	0.393	12.33	0.840
5.75	0.046	8.35	0.230	13.87	0.954	5.25	0.908	7.96	0.456	12.60	0.870
5.80	0.079	8.45	0.290	14.12	0.941	5.34	0.886	8.04	0.323	12.80	0.869
5.84	0.591	8.55	0.263	14.43	0.965	5.47	0.886	8.09	0.372	12.98	0.840
5.88	0.771	8.65	0.143	15.08	0.974	5.56	0.872	8.15	0.527	13.15	0.789
5.93	0.805	8.91	0.593	15.43	0.966	5.61	0.833	8.21	0.575	13.29	0.735
5.97	0.901	9.01	0.695	16.18	0.973	5.65	0.791	8.31	0.366	13.38	0.671
6.03	0.914	9.08	0.745	17.18	0.965	5.71	0.341	8.35	0.264	13.45	0.704

TABLE 16-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 11 (CONT.)		CURVE 12 (CONT.)		CURVE 13 (CONT.)		CURVE 13 (CONT.)		CURVE 13 (CONT.)		CURVE 13 (CONT.)	
13.48	0.783	1.558	0.801	2.67	0.819	4.32	0.875	6.20	0.872	8.09	0.773
13.59	0.840	1.591	0.767	2.71	0.862	4.41	0.900	6.36	0.886	8.18	0.550
13.75	0.855	1.617	0.645	2.74	0.868	4.46	0.900	6.40	0.862	8.24	0.306
14.08	0.855	1.670	0.259	2.74	0.833	4.49	0.912	6.40	0.795	8.30	0.216
14.99	0.816	1.685	0.240	2.78	0.860	4.60	0.877	6.43	0.868	8.37	0.255
		1.700	0.254	2.82	0.860	4.65	0.895	6.48	0.800	8.43	0.349
CURVE 12		1.714	0.343	2.83	0.880	4.73	0.883	6.51	0.852	8.50	0.092
T = 293.		1.747	0.456	2.87	0.880	4.84	0.906	6.57	0.798	8.55	0.072
		1.793	0.490	2.89	0.867	4.93	0.890	6.61	0.842	8.61	0.106
0.275	0.000	1.834	0.501	2.92	0.880	5.00	0.901	6.63	0.793	8.68	0.604
0.303	0.547	1.9[illegible]2	0.526	3.02	0.880	5.04	0.908	6.68	0.869	8.75	0.808
0.313	0.747	1.968	0.554	3.06	0.880	5.11	0.920	6.72	0.828	8.82	0.857
0.327	0.612	1.989	0.562	3.08	0.888	5.14	0.909	6.74	0.791	9.00	0.884
0.336	0.845	2.021	0.544	3.13	0.869	5.17	0.920	6.80	0.642	9.15	0.897
0.351	0.878	2.038	0.484	3.16	0.883	5.20	0.897	6.80	0.569	9.42	0.897
0.369	0.904	2.050	0.310	3.18	0.874	5.24	0.912	6.84	0.589	9.51	0.910
0.391	0.918	2.066	0.198	3.21	0.835	5.29	0.888	6.88	0.580	9.66	0.762
0.419	0.926	2.122	0.114	3.25	0.868	5.32	0.897	6.93	0.564	9.76	0.721
0.567	0.926	2.156	0.060	3.28	0.813	5.35	0.879	6.98	0.741	9.84	0.779
0.609	0.933	2.195	0.023	3.29	0.750	5.36	0.911	7.01	0.792	9.91	0.836
0.838	0.933	2.259	0.012	3.31	0.704	5.40	0.920	7.03	0.749	10.12	0.880
0.900	0.914	2.350	0.012	3.34	0.641	5.42	0.906	7.07	0.770	10.24	0.919
0.943	0.914	2.418	0.028	3.35	0.652	5.49	0.906	7.11	0.758	10.48	0.700
1.002	0.925	2.476	0.055	3.36	0.536	5.56	0.860	7.17	0.782	10.58	0.537
1.088	0.904	2.516	0.066	3.40	0.718	5.59	0.882	7.20	0.803	10.81	0.801
1.119	0.853	2.572	0.067	3.43	0.784	5.61	0.862	7.26	0.818	10.88	0.916
1.155	0.795	2.635	0.048	3.47	0.835	5.67	0.403	7.26	0.842	11.07	0.938
1.197	0.765	2.688	0.019	3.51	0.806	5.69	0.130	7.34	0.864	11.51	0.938
1.226	0.792			3.54	0.865	5.71	0.094	7.37	0.800	11.74	0.918
1.271	0.859	CURVE 13		3.60	0.879	5.75	0.145	7.42	0.555	11.95	0.812
1.289	0.867	T = 293.		3.67	0.888	5.79	0.605	7.45	0.381	12.03	0.753
1.312	0.857			3.81	0.888	5.84	0.808	7.50	0.361	12.22	0.729
1.344	0.766	2.50	0.879	3.83	0.898	5.88	0.790	7.56	0.412	12.30	0.868
1.364	0.701	2.56	0.878	3.93	0.898	5.93	0.814	7.61	0.389	12.39	0.886
1.391	0.633	2.56	0.834	3.96	0.885	5.97	0.852	7.68	0.461	12.47	0.936
1.422	0.718	2.58	0.858	4.01	0.902	6.02	0.827	7.73	0.699	12.76	0.959
1.437	0.778	2.60	0.829	4.06	0.902	6.04	0.657	7.79	0.837	13.04	0.944
1.457	0.820	2.62	0.858	4.16	0.902	6.06	0.718	7.86	0.845	13.66	0.966
1.488	0.836	2.65	0.880	4.19	0.870	6.11	0.691	7.91	0.869	14.39	0.942
1.526	0.823	2.66	0.856	4.23	0.815	6.14	0.808	8.03	0.822	15.08	0.874

TABLE 16-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 13 (CONT.)	
15.36	0.889
15.50	0.920
15.95	0.952
16.72	0.914
17.39	0.958
18.59	0.958
19.76	0.913
20.53	0.929
21.28	0.922
22.12	0.877
22.57	0.831
23.29	0.810
23.58	0.727
25.00	0.694
CURVE 14	
T = 293.	
2.50	0.837
2.58	0.840
2.67	0.848
2.76	0.848
2.81	0.839
2.83	0.826
2.88	0.839
2.91	0.823
2.94	0.837
3.00	0.837
3.02	0.848
3.05	0.832
3.07	0.840
3.17	0.840
3.19	0.846
3.23	0.840
3.28	0.838
3.30	0.819
3.31	0.786
3.34	0.730
3.34	0.658
3.39	0.634

λ	τ
CURVE 14 (CONT.)	
3.39	0.563
3.41	0.589
3.44	0.546
3.45	0.681
3.47	0.725
3.50	0.747
3.52	0.664
3.54	0.801
3.57	0.839
3.63	0.851
3.72	0.860
3.98	0.865
4.01	0.890
4.04	0.861
4.12	0.875
4.26	0.875
4.36	0.881
4.55	0.886
4.78	0.881
4.95	0.881
5.00	0.897
5.05	[illegible]
5.07	0.895
5.27	0.895
5.33	0.905
5.37	0.898
5.46	0.898
5.51	0.886
5.56	0.863
5.61	0.834
5.64	0.803
5.69	0.748
5.73	0.310
5.76	0.218
5.81	0.268
5.87	0.603
5.90	0.744
5.96	0.805
6.01	0.828
6.12	0.788

λ	τ
CURVE 14 (CONT.)	
6.21	0.861
6.30	0.876
6.54	0.883
6.59	0.859
6.65	0.869
6.71	0.834
6.78	0.703
6.81	0.625
6.89	0.598
6.96	0.558
7.00	0.762
7.07	0.799
7.15	0.776
7.18	0.729
7.26	0.714
7.32	0.749
7.39	0.768
7.43	0.750
7.58	0.702
7.68	0.643
7.84	0.572
8.03	0.512
8.18	0.527
8.24	0.502
8.37	0.394
8.43	0.448
8.67	0.377
8.81	0.547
8.95	0.597
9.07	0.671
9.20	0.749
9.58	0.774
9.77	0.734
9.82	0.773
9.96	0.789
10.11	0.753
10.22	0.774
10.32	0.798
10.52	0.785
10.64	0.813

λ	τ
CURVE 14 (CONT.)	
10.72	0.834
10.85	0.846
11.10	0.842
11.45	0.861
11.78	0.845
12.14	0.842
12.25	0.825
12.39	0.868
12.82	0.897
13.00	0.870
13.39	0.828
13.53	0.871
13.55	0.913
13.93	0.905
14.01	0.933
14.45	0.927
14.81	0.939
15.22	0.921
15.48	0.935
16.29	0.930
19.27	0.930
19.61	0.923
21.05	0.923
21.51	0.914
22.27	0.933
24.10	0.871
24.63	0.826
25.00	0.808
CURVE 15	
T = 293.	
2.83	0.799
2.92	0.790
2.99	0.768
3.05	0.782
3.17	0.782
3.24	0.761
3.33	0.159
3.34	0.065

λ	τ
CURVE 15 (CONT.)	
3.38	0.112
3.41	0.030
3.50	0.632
3.55	0.782
3.64	0.847
4.02	0.848
4.20	0.860
4.34	0.853
5.00	0.854
5.36	0.829
5.62	0.803
5.79	0.757
5.87	0.003
6.02	0.039
6.09	0.779
6.27	0.802
6.35	0.774
6.57	0.806
6.70	0.055
6.87	0.019
6.86	0.469
7.10	0.510
7.29	0.333
7.64	0.520
7.86	0.483
7.86	0.076
8.27	0.039
8.53	0.098
8.66	0.019
9.00	0.010
9.33	0.032
9.33	0.540
9.73	0.451
10.01	0.774
10.37	0.436
10.79	0.387
10.79	0.768
10.99	0.750
11.53	0.772
11.53	0.664

λ	τ
CURVE 15 (CONT.)	
12.12	0.646
12.56	0.616
12.97	0.786
14.56	0.804
16.53	0.815
18.42	0.840
20.00	0.816
20.00	0.783
21.01	0.784
22.88	0.785
23.87	0.785
24.75	0.722
26.25	0.523
27.25	0.404
28.25	0.418
28.25	0.532
31.55	0.622
37.31	0.733
44.05	0.753
53.76	0.813
61.73	0.848
71.94	0.847
94.34	0.830
65.	0.808
CURVE 16	
T = 293.	
2.00	0.897
2.20	0.897
2.27	0.881
2.36	0.900
2.75	0.900
2.84	0.859
2.88	0.886
2.93	0.862
2.98	0.886
3.06	0.893
3.19	0.893
3.25	0.873

TABLE 16-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 16 (CONT.)		CURVE 16 (CONT.)		CURVE 16 (CONT.)		CURVE 16 (CONT.)		CURVE 17 (CONT.)		CURVE 17 (CONT.)	
3.28	0.842	6.77	0.559	8.46	0.256	11.27	0.892	3.04	0.408	5.91	0.349
3.32	0.795	6.79	0.581	8.53	0.229	11.49	0.892	3.13	0.418	5.93	0.423
3.34	0.671	6.82	0.559	8.59	0.206	11.64	0.863	3.16	0.441	5.96	0.446
3.34	0.601	6.87	0.420	8.65	0.115	11.82	0.796	3.24	0.469	5.96	0.470
3.38	0.591	6.90	0.397	8.69	0.077	11.90	0.772	3.31	0.484	6.00	0.483
3.38	0.543	6.95	0.420	8.72	0.109	11.95	0.792	3.35	0.478	6.00	0.499
3.41	0.518	6.98	0.487	8.78	0.282	12.01	0.838	3.37	0.449	6.08	0.518
3.43	0.564	7.01	0.699	8.82	0.371	12.05	0.859	3.38	0.416	6.21	0.518
3.45	0.700	7.04	0.749	8.85	0.453	12.13	0.834	3.40	0.388	6.29	0.531
3.48	0.782	7.10	0.769	8.90	0.557	12.26	0.876	3.43	0.368	6.32	0.542
3.55	0.852	7.14	0.731	9.00	0.643	12.38	0.830	3.47	0.399	6.38	0.549
3.59	0.879	7.21	0.629	9.04	0.690	12.51	0.866	3.49	0.434	6.40	0.559
3.67	0.898	7.24	0.680	9.08	0.727	12.67	0.883	3.53	0.446	6.43	0.544
4.01	0.902	7.27	0.706	9.18	0.765	12.83	0.883	3.53	0.477	6.43	0.559
4.78	0.902	7.31	0.677	9.29	0.765	12.98	0.866	3.57	0.521	6.51	0.559
4.83	0.895	7.34	0.699	9.37	0.740	13.08	0.828	3.59	0.547	6.53	0.569
5.00	0.904	7.39	0.744	9.44	0.714	13.21	0.766	3.65	0.564	6.56	0.559
5.13	0.890	7.43	0.770	9.50	0.812	13.31	0.689	3.77	0.561	6.61	0.552
5.22	0.901	7.49	0.788	9.54	0.871	13.36	0.659	3.91	0.544	6.64	0.557
5.34	0.901	7.60	0.788	9.62	0.898	13.41	0.699	4.06	0.519	6.65	0.544
5.50	0.880	7.67	0.757	9.74	0.889	13.46	0.790	4.16	0.501	6.67	0.560
5.59	0.867	7.72	0.707	9.85	0.899	13.51	0.831	4.24	0.491	6.73	0.528
5.65	0.841	7.77	0.639	9.91	0.892	13.64	0.856	4.35	0.491	6.75	0.495
5.67	0.791	7.81	0.480	9.97	0.844	14.01	0.854	4.45	0.487	6.78	0.488
5.70	0.397	7.83	0.414	10.05	0.687	14.19	0.854	4.61	0.487	6.82	0.447
5.74	0.052	7.85	0.377	10.08	0.638	14.34	0.835	4.71	0.500	6.87	0.395
5.77	0.031	7.88	0.397	10.15	0.624	14.60	0.830	4.89	0.525	6.88	0.411
5.78	0.060	7.90	0.432	10.21	0.675	15.00	0.807	5.17	0.568	6.91	0.415
5.85	0.586	7.93	0.453	10.24	0.693			5.37	0.595	6.94	0.423
5.89	0.724	7.97	0.410	10.27	0.710	CURVE 17		5.49	0.595	6.97	0.412
5.96	0.771	8.02	0.301	10.32	0.691	T = 293.		5.57	0.590	7.01	0.437
5.99	0.840	8.05	0.281	10.38	0.663			5.65	0.523	7.06	0.483
6.04	0.864	8.08	0.303	10.44	0.721	2.53	0.566	5.71	0.478	7.11	0.483
6.10	0.875	8.13	0.462	10.51	0.773	2.64	0.566	5.72	0.438	7.17	0.473
6.30	0.870	8.16	0.551	10.59	0.802	2.69	0.546	5.74	0.419	7.20	0.448
6.57	0.876	8.21	0.594	10.73	0.836	2.74	0.529	5.75	0.339	7.23	0.438
6.60	0.859	8.25	0.560	10.87	0.8[illegible]4	2.78	0.499	5.79	0.248	7.25	0.420
6.64	0.831	8.29	0.386	11.01	0.797	2.82	0.459	5.81	0.234	7.28	0.431
6.71	0.533	8.33	0.258	11.06	0.831	2.87	0.432	5.85	0.250	7.31	0.431
6.73	0.512	8.37	0.189	11.13	0.862	2.95	0.408	5.87	0.321	7.37	0.442

TABLE 16-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 17(CONT.)		CURVE 17(CONT.)		CURVE 17(CONT.)		CURVE 17(CONT.)		CURVE 18(CONT.)		CURVE 19(CONT.)	
7.40	0.448	11.06	0.454	14.54	0.590	19.18	0.583	0.341	0.804	0.259	0.018
7.43	0.444	11.12	0.458	14.64	0.581	19.28	0.600	0.350	0.832	0.261	0.041
7.47	0.450	11.18	0.449	14.77	0.596	19.38	0.600	0.356	0.800	0.262	0.016
7.49	0.445	11.25	0.457	14.83	0.581	19.42	0.585	0.385	0.861	0.261	0.010
7.54	0.445	11.32	0.452	15.02	0.589	19.55	0.581	0.404	0.884	0.268	0.000
7.56	0.438	11.39	0.461	15.16	0.581	19.76	0.594	0.452	0.901	0.357	0.000
7.59	0.439	11.49	0.458	15.21	0.557	20.01	0.581	0.603	0.913	0.364	0.015
7.62	0.428	11.62	0.465	15.28	0.598	20.08	0.592	0.751	0.931	0.369	0.030
7.66	0.428	11.67	0.479	15.36	0.583	20.24	0.600	0.908	0.931	0.372	0.048
7.69	0.417	11.75	0.468	15.46	0.589	20.39	0.588	1.064	0.936	0.374	0.069
7.73	0.417	11.84	0.484	15.55	0.602	20.50	0.588	1.220	0.928	0.376	0.146
7.76	0.401	11.91	0.475	15.67	0.586	20.65	0.597	1.249	0.930	0.389	0.775
7.79	0.401	11.99	0.484	15.73	0.586	20.68	0.600	1.341	0.929	0.398	0.817
7.82	0.384	12.07	0.478	15.80	0.600	20.88	0.593	1.405	0.893	0.393	0.842
7.86	0.381	12.15	0.492	15.86	0.600	20.95	0.588	1.438	0.891	0.397	0.863
7.90	0.356	12.27	0.478	15.95	0.573	21.15	0.598	1.460	0.899	0.403	0.830
7.93	0.356	12.34	0.492	16.10	0.573	21.28	0.598	1.502	0.915	0.411	0.895
7.97	0.345	12.42	0.481	16.16	0.558	21.57	0.591	1.554	0.922	0.422	0.908
8.02	0.358	12.49	0.495	16.26	0.536	21.67	0.599	1.600	0.917	0.700	0.908
8.09	0.360	12.60	0.488	16.43	0.536	21.77	0.599	1.631	0.891	0.700	0.912
8.12	0.357	12.67	0.507	16.53	0.527	22.03	0.591	1.672	0.855	0.715	0.912
8.16	0.360	12.78	0.500	16.66	0.535	22.21	0.598	1.702	0.854	0.741	0.920
8.20	0.353	12.88	0.516	16.77	0.560	22.59	0.592	1.725	0.862	0.763	0.918
8.23	0.357	12.98	0.517	16.94	0.569	22.78	0.599	1.758	0.876	0.788	0.918
8.26	0.344	13.05	0.528	17.04	0.584	23.05	0.594	1.794	0.888	0.815	0.923
8.29	0.344	13.17	0.518	17.10	0.591	23.28	0.594	1.807	0.888	0.844	0.902
8.38	0.372	13.25	0.536	17.16	0.579	23.49	0.599	1.828	0.878	0.890	0.874
8.50	0.361	13.34	0.526	17.29	0.584	23.60	0.593	1.852	0.858	0.915	0.873
8.70	0.361	13.43	0.554	17.34	0.598			1.872	0.834	0.941	0.889
8.81	0.347	13.50	0.537	17.40	0.606	CURVE 18		1.894	0.813	0.968	0.889
9.05	0.335	13.57	0.537	17.46	0.598	T = 293.		1.913	0.813	1.003	0.876
9.09	0.322	13.64	0.553	17.53	0.579			1.938	0.827	1.030	0.883
9.26	0.322	13.75	0.537	18.11	0.600	0.288	0.000	1.970	0.850	1.060	0.896
9.50	0.346	13.80	0.548	18.27	0.581	0.296	0.183	2.000	0.847	1.122	0.684
9.64	0.370	13.85	0.569	18.37	0.588	0.301	0.440			1.130	0.836
9.83	0.380	13.96	0.556	18.49	0.603	0.304	0.596	CURVE 19		1.141	0.797
9.95	0.400	14.07	0.584	18.65	0.589	0.308	0.662	T = 293.		1.161	0.726
10.21	0.428	14.17	0.567	18.78	0.589	0.312	0.689			1.172	0.692
10.66	0.463	14.27	0.591	18.89	0.599	0.319	0.726	0.250	0.000	1.181	0.684
10.98	0.463	14.42	0.581	18.99	0.588	0.329	0.764	0.257	0.008	1.191	0.690

TABLE 16-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF LUCITE (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

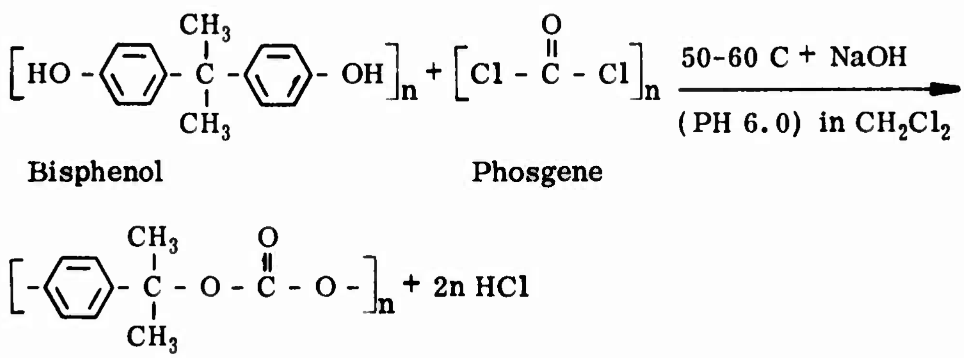
λ	τ	λ	τ	λ	τ	λ	τ
CURVE 19(CONT.)		CURVE 19(CONT.)		CURVE 20(CONT.)		CURVE 21(CONT.)	
1.191	0.730	1.877	0.585	0.250	0.000	0.552	0.926
1.214	0.825	1.879	0.554	0.254	0.009	0.600	0.931
1.236	0.367	1.886	0.415	0.257	0.020	0.647	0.933
1.259	0.892	1.886	0.333	0.259	0.044	0.668	0.933
1.273	0.873	1.891	0.268	0.279	0.415	0.700	0.935
1.288	0.883	1.899	0.253	0.284	0.531		
1.318	0.866	1.909	0.271	0.290	0.602		
1.347	0.692	1.909	0.319	0.297	0.684		
1.367	0.629	1.914	0.339	0.302	0.714		
1.377	0.657	1.914	0.382	0.308	0.753		
1.388	0.646	1.916	0.417	0.316	0.789		
1.388	0.566	1.916	0.456	0.323	0.813		
1.401	0.679	1.924	0.470	0.333	0.840		
1.401	0.695	1.928	0.502	0.344	0.860		
1.421	0.695	1.946	0.444	0.353	0.873		
1.470	0.807	1.953	0.467	0.361	0.881		
1.500	0.849	1.963	0.483	0.369	0.889		
1.550	0.849	1.976	0.559	0.375	0.893		
1.584	0.818	1.991	0.591	0.389	0.900		
1.607	0.783	2.028	0.578	0.700	0.900		
1.608	0.763	2.051	0.504				
1.610	0.737	2.064	0.473	CURVE 21			
1.643	0.645	2.079	0.353	T = 293.			
1.654	0.508	2.093	0.253				
1.662	0.355	2.108	0.262	0.250	0.000		
1.670	0.134	2.116	0.211	0.265	0.199		
1.677	0.104	2.120	0.147	0.277	0.400		
1.688	0.123	2.127	0.133	0.289	0.598		
1.686	0.151	2.139	0.153	0.294	0.655		
1.698	0.183	2.148	0.173	0.303	0.713		
1.709	0.170	2.148	0.203	0.310	0.757		
1.727	0.209	2.165	0.215	0.320	0.800		
1.741	0.300	2.181	0.031	0.327	0.830		
1.769	0.420	2.193	0.000	0.339	0.857		
1.769	0.447	2.226	0.000	0.351	0.883		
1.784	0.429			0.366	0.900		
1.809	0.558	CURVE 20		0.378	0.909		
1.815	0.584	T = 293.		0.400	0.913		
1.828	0.600			0.450	0.913		
1.850	0.550	0.200	0.000	0.500	0.920		

4.17. Polycarbonate Plastics

Polycarbonates are transparent, faintly amber-colored, thermoplastic materials showing good dimensional stability, thermal resistance, and electrical properties, as well as good tensile and impact strength. Their unique hardness properties allow polycarbonates to substitute for metals in some applications, as in plastic rivets and bolts.

Trade names of polycarbonates are "Lexan" for General Electric, "Merlon" for Mobay, "Lexel" (fibre), "Makrolon", and "Panlite". The softening point of Lexan is 428 K and that of Merlon is 410 K. The heat distortion temperature and mold temperature is 406-411 K and 561-589 K, respectively.

Polycarbonates are formed by the condensation of polyphenols (usually Bis-phenol-A) with phosgene. The resulting thermoplastic polymer can be considered an ester of carbonic acid and bisphenol A.



Polycarbonate

The molecular weight of commercial polycarbonate plastics is up to 30000 (degree of polymerizationc. 120), beyond which increasing viscosity limits practical processing. The commonest polycarbonate unit cell contains 4 chains and 8 fundamental units; identity period 21.5 Å. It can be dissolved by certain chlorinated hydrocarbons (dichloroform, methylene chloride, di-, tri-, and tetrachloroethane, hot chlorobenzene), pyridine, dioxan, cyclohexanone, and hot phenols. It will be swollen by acetone, benzene, and carbon tetrachloride. It can be decomposed by hot alcoholic alkalis, amines, and other organic bases, and its surface attack by aq. alkalis.

Polycarbonate has density 1.20 g cm^{-3}, has the second order (glass) transition temperature at about 420 K, softens above 430 K, decomposes around 580 K, and is serviceable up to 410 K. Its tensile strength halves at 400 K. Its dielectric constants are 2.7-3.1 over the range 50-10^{10} Hz. Its resistivity is about 10^{16} Ω cm at room temperature and 10^{14} Ω cm at 400 K. Dielectric strength of very thin films is 120 KV/mm and 100 KV/mm for 0.05-0.125 mm films. Its electrical properties show little dependence

on frequency, and are not greatly changed by heating to 410 K or by long immersion in water.

Polycarbonate has specific heat 0.28-0.30, thermal conductivity 0.00192 W cm^{-1} K^{-1}, and thermal expansion coefficient 0.6-0.7 x 10^{-4} K^{-1} (0.76 x 10^{-8} K^{-1} at 30-410 K). It shrinks 0.5 ~ 0.7% when molding and it is self-extinguishing by the ASTM D-635 test.

a. Normal Spectral Emittance (Wavelength Dependence)

There is no data on emittance of polycarbonate plastics available. However, Pregelhof, Franey, and Haas [T77125] used a one-dimensional model, assuming uniform properties, and gave the emittance $\epsilon(\lambda)$, the absorptance $\alpha(\lambda)$, the transmittance $\tau(\lambda)$, and the reflectance $\rho(\lambda)$ of a polymer sheet in the following expressions:

$$\epsilon(\lambda) = \alpha(\lambda) = \frac{(1-R)\,[(1+R)\sinh ad + (1-R)\,(\cosh ad - 1)]}{(1+R^2)\sinh ad + (1-R^2)\cosh ad} \tag{4.17-1}$$

$$\tau(\lambda) = \frac{(1-R)^2}{(1+R^2)\sinh ad + (1-R^2)\cosh ad} \tag{4.17-2}$$

$$\rho(\lambda) = \frac{2R\,[R\sinh ad + (1-R)\cosh ad]}{(1+R^2)\sinh ad + (1-R^2)\cosh ad} \tag{4.17-3}$$

where $R = (n-1/n+1)^2$ and n is the refractive index, d is the thickness of the sample, and a is the absorption coefficient. Therefore, the absorptance can be calculated from the above equations.

For the polycarbonate plastic bulk materials, it can be assumed that

$$e^{ad} \gg Re^{-ad} \tag{4.17-4}$$

which enables Eqs. (4.17-1, 4.17-2, and 4.17-3) to become the following:

$$\epsilon(\lambda) = \alpha(\lambda) \cong (1-R)\,[1 - (1-R)\,e^{-ad} - Re^{-2ad}] \tag{4.17-5}$$

$$\tau(\lambda) \cong (1-R)^2\,e^{-ad} \tag{4.17-6}$$

$$\rho(\lambda) \cong R\,[1 + (1-R)\,e^{-2ad}] \tag{4.17-7}$$

By using these equations together with the experimental data of transmittance and reflectance, the emittance can be calculated. Here we used d = 4 mm for the

calculation. The calculated results of emittance for bulk polycarbonate plastic samples with thickness 4 mm at 293 K are shown in Table 17-1 and Figure 17-1 with an estimated uncertainty of about ±20%.

TABLE 17-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε
THICKNESS 4MM		THICKNESS 4MM	
T = 293		T = 293 (CONT.)	
0.6[illegible]	0.12	12.50	0.940
0.75	0.05	13.00	0.931
0.92	0.05	13.50	0.940
1.00	0.05	14.00	0.949
1.19	0.05	14.50	0.969
1.34	0.10	15.00	0.943
1.39	0.16		
1.47	0.07		
1.63	0.60		
1.65	0.77		
1.69	0.72		
1.73	0.33		
1.76	0.37		
1.83	0.43		
1.87	0.46		
1.95	0.32		
2.00	0.41		
2.50	0.94		
2.80	0.95		
3.00	0.92		
3.50	0.953		
4.00	0.961		
4.50	0.960		
5.00	0.962		
5.50	0.955		
6.00	0.959		
6.50	0.957		
7.00	0.963		
7.50	0.972		
8.00	0.938		
8.50	0.914		
9.00	0.935		
9.50	0.944		
10.00	0.939		
10.50	0.946		
11.00	0.953		
11.50	0.947		
12.00	0.951		
12.50	0.951		

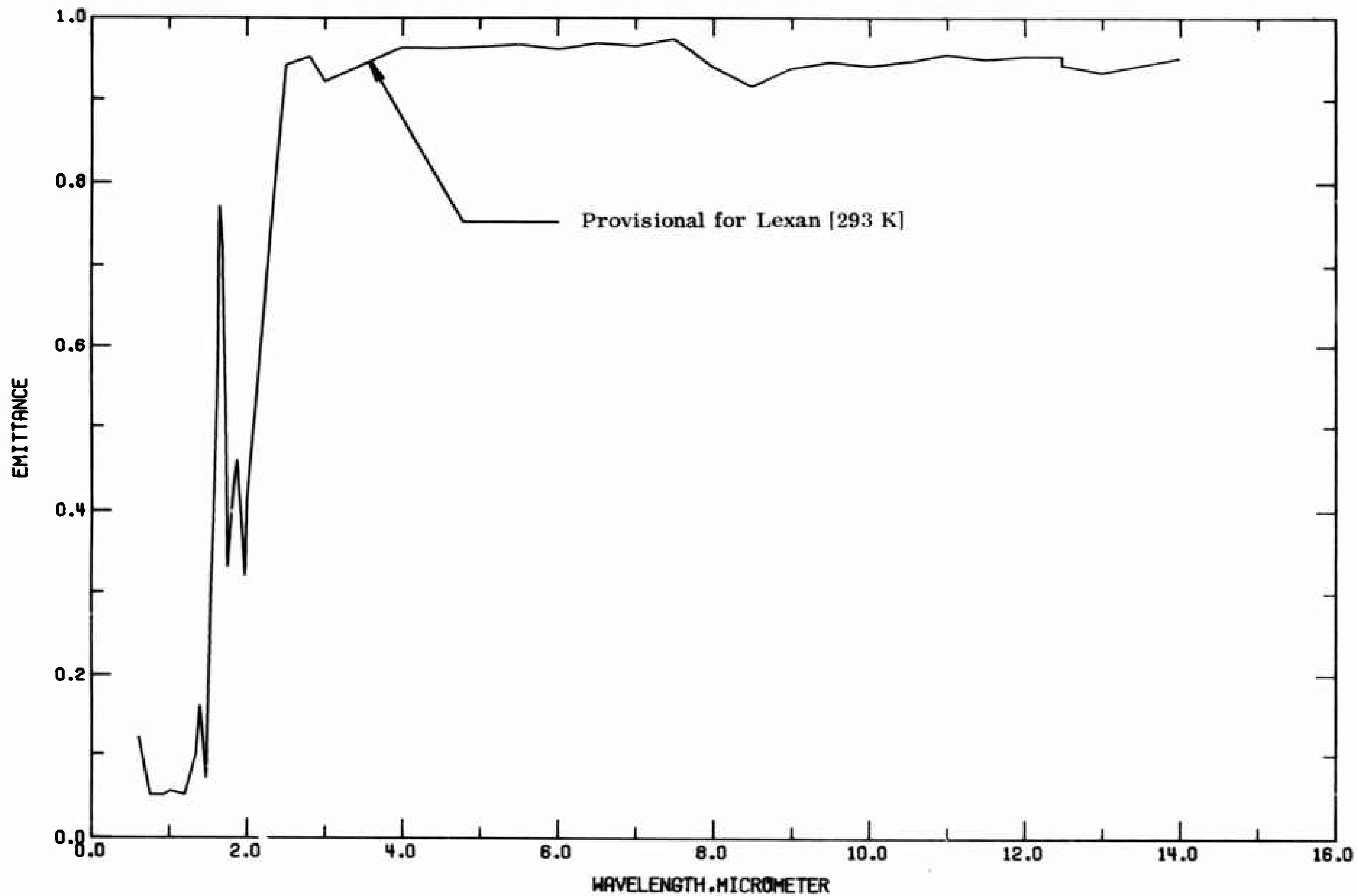


FIGURE 17-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE).

b. Normal Spectral Reflectance (Wavelength Dependence)

Only Vinokanova, Cherkusov, and Kisilitsu [T71819] have measured the normal spectral reflectance in the 0.05-0.25 μm wavelength region. We can only roughly estimate the normal spectral reflectance by the results of angular reflectance. The provisional normal spectral reflectance values are slightly lower than that of the angular reflectance and are shown in Table 17-2 and Figure 17-2 with an uncertainty of about ±30%.

TABLE 17-2. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ
LEXAN		LEXAN	
T = 293		T = 293 (CONT.)	
0.06	0.07	11.00	0.047
0.10	0.11	11.50	0.053
0.25	0.13	12.00	0.049
0.60	0.11	12.50	0.057
0.75	0.17	13.00	0.061
0.92	0.148	13.50	0.060
1.00	0.150	14.00	0.051
1.19	0.190	14.50	0.051
1.34	0.170	15.00	0.057
1.39	0.165		
1.47	0.165		
1.53	0.128		
1.65	0.170		
1.75	0.200		
1.78	0.064		
1.83	0.095		
1.87	0.030		
1.98	0.030		
2.00	0.030		
2.30	0.058		
2.50	0.050		
2.80	0.047		
2.92	0.031		
3.00	0.034		
3.80	0.046		
4.00	0.039		
4.50	0.040		
5.00	0.033		
5.50	0.035		
6.00	0.041		
6.50	0.033		
7.00	0.037		
7.50	0.028		
8.00	0.062		
8.50	0.086		
9.00	0.064		
9.50	0.056		
10.00	0.061		
10.60	0.054		

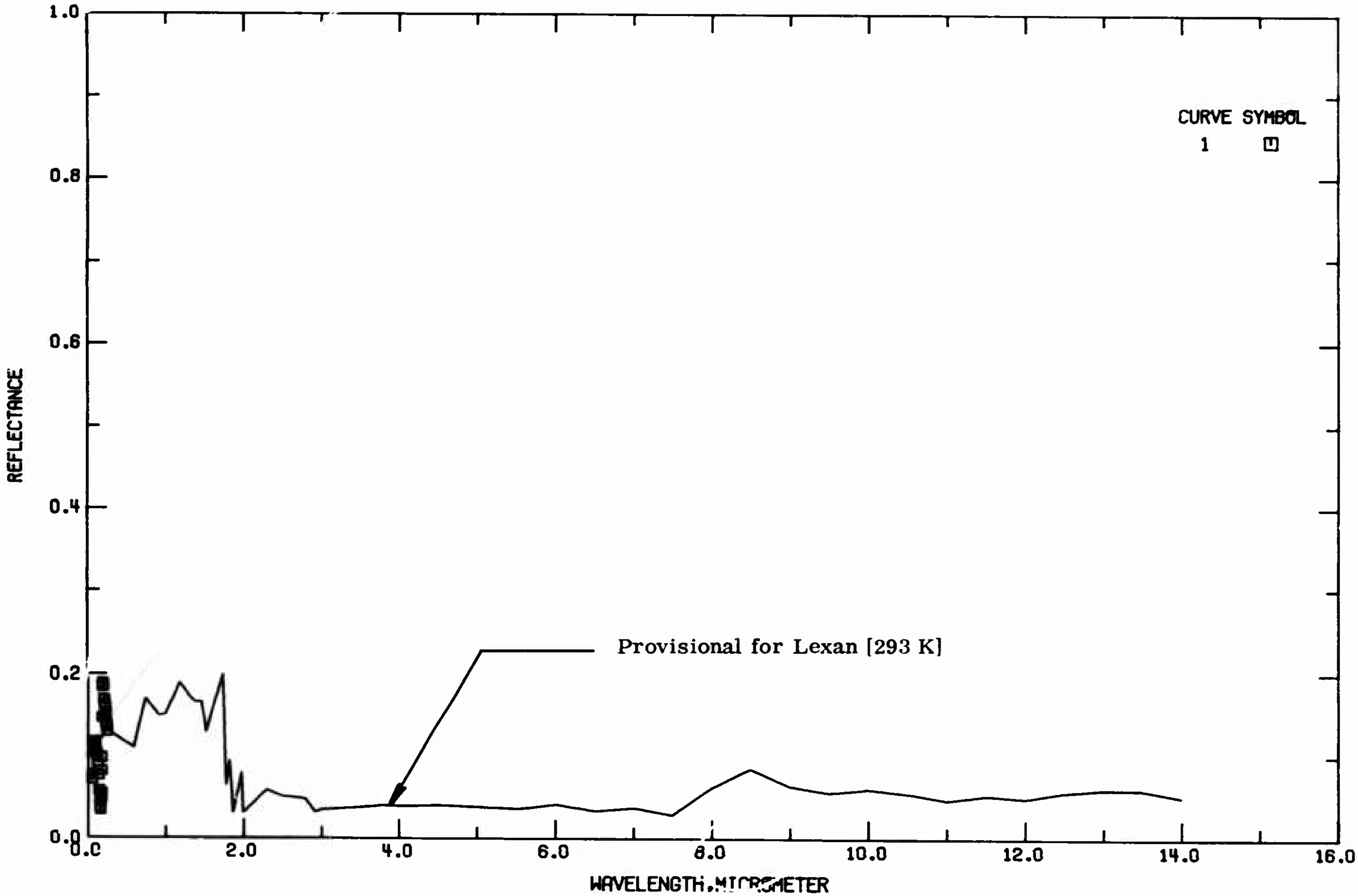


FIGURE 17-2. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE).

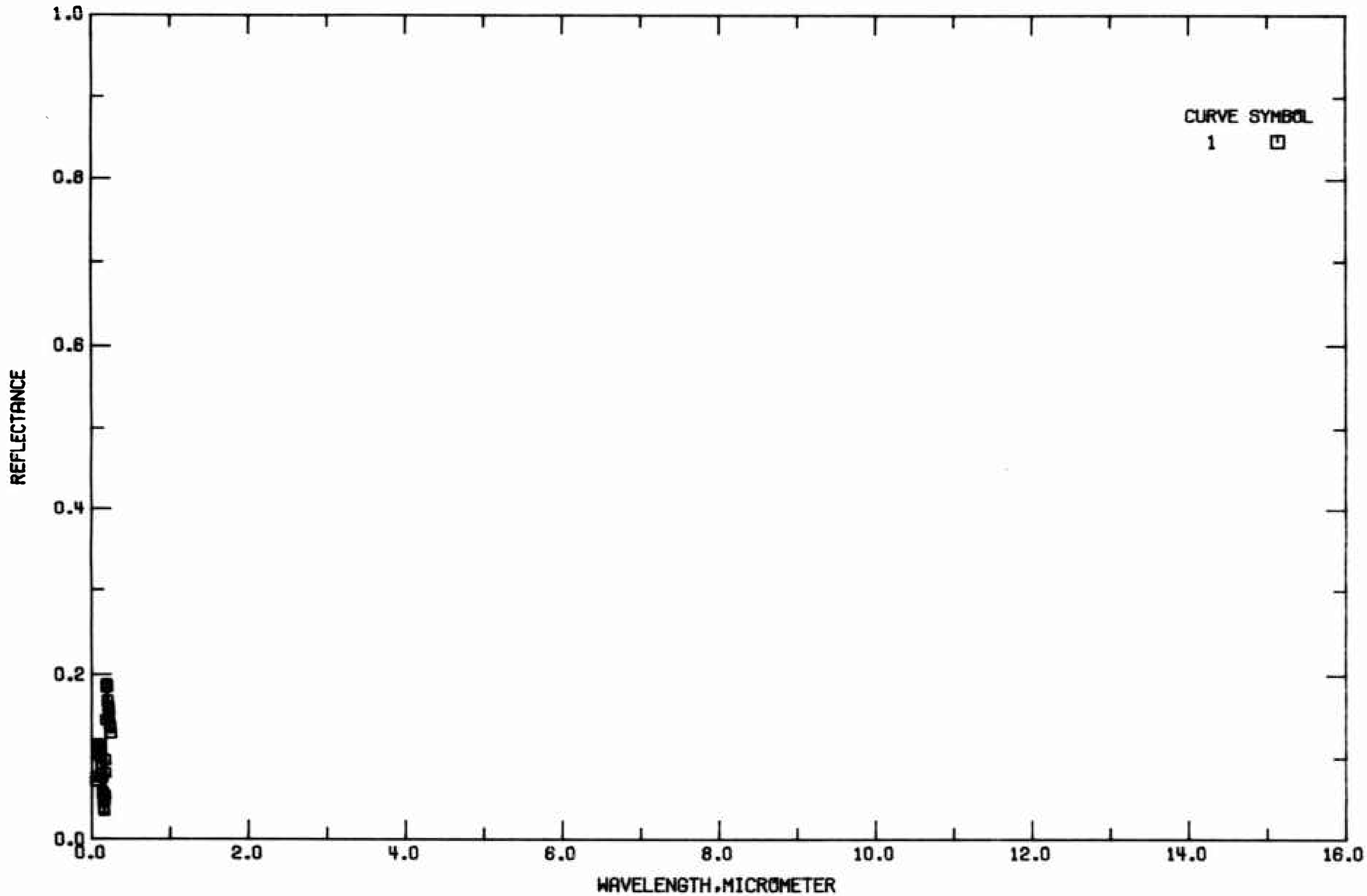


FIGURE 17-3. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE).

TABLE 17-3. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF POLYCARBONATE PLASTICS (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T71819, T72331	Vinokurova, L.N., Cherkasov, Yu.A., and Kisilitsa, P.P.	1973	0.05–0.25	293	Polycarbonate	Polymer film with thickness about several μm was deposited from solution on a polished glass face plate; a VMR-2 vacuum monochromator at a resolution of 1.6 mm was used and a glow discharge in hydrogen and technical helium was used as radiation source; data were estracted from figure; $\theta \sim 0°$.

TABLE 17-4. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ
CURVE 1	
T = 293.	
0.0554	0.071
0.0592	0.077
0.0833	0.112
0.0896	0.116
0.0977	0.111
0.1064	0.105
0.1154	0.102
0.1219	0.101
0.1296	0.093
0.1408	0.076
0.1485	0.057
0.1566	0.044
0.1605	0.037
0.1662	0.034
0.1730	0.048
0.1756	0.054
0.1797	0.082
0.1798	0.098
0.1879	0.145
0.1933	0.185
0.1985	0.189
0.2048	0.186
0.2119	0.169
0.2176	0.162
0.2242	0.158
0.2315	0.151
0.2356	0.139
0.2454	0.136
0.2511	0.129

c. Angular Spectral Reflectance (Wavelength Dependence)

Only Grimm, Linfored, Dillow, Spinak, and Mills [A00001] have measured the angular spectral reflectance for a 290 mm thick disk of Lexan in the 2-15 μm region with the incident angle of 15° and 45°, respectively for curves 1 and 2. The reflectance values increase slightly with the increasing of incident angle.

Pregelhof, Francy, and Haas [T77125] calculated the absorption coefficient $a = 50\ cm^{-1}$ or larger in the wavelength region $\lambda > 4\ \mu m$. Therefore, Eq. (4.17-7) becomes

$$\rho(\lambda) \cong R = (n - 1/n + 1)^2 \tag{4.17-8}$$

which is independent of the thickness of the sample and depends only on index of refraction. However, the data of index of refraction are not available in the wavelength region above 1 μm. Thus, Eq. (4.17-8) is not applicable here.

For the wavelength region below 2 μm, with the aid of the transmittance data, the reflectance can be calculated. Together with the experimental data of Grimm, et al., which is shown in Table 17-3, the provisional values of angular reflectance are shown in Table 17-2 and Figure 17-4 with an estimated uncertainty of about ± 30%.

TABLE 17-5. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ
LEXAN $\theta=15°$ T = 293		LEXAN $\theta=15°$ T = 293 (CONT.)	
0.06	0.071	11.00	0.048
0.10	0.115	11.50	0.054
0.25	0.136	12.00	0.050
0.60	0.115	12.50	0.058
0.74	0.170	13.00	0.061
0.75	0.173	13.50	0.061
0.92	0.149	14.00	0.052
1.00	0.150	14.50	0.052
1.19	0.195	15.00	0.058
1.34	0.174		
1.39	0.168		
1.47	0.168		
1.53	0.130		
1.65	0.174		
1.75	0.208		
1.78	0.065		
1.83	0.097		
1.87	0.031		
1.98	0.032		
2.00	0.081		
2.30	0.051		
2.50	0.051		
2.92	0.032		
3.00	0.035		
3.30	0.041		
4.00	0.040		
4.50	0.041		
5.00	0.039		
5.50	0.036		
6.00	0.042		
6.50	0.034		
7.00	0.038		
7.50	0.029		
8.00	0.063		
8.50	0.087		
9.00	0.065		
9.50	0.057		
10.00	0.062		
10.50	0.055		

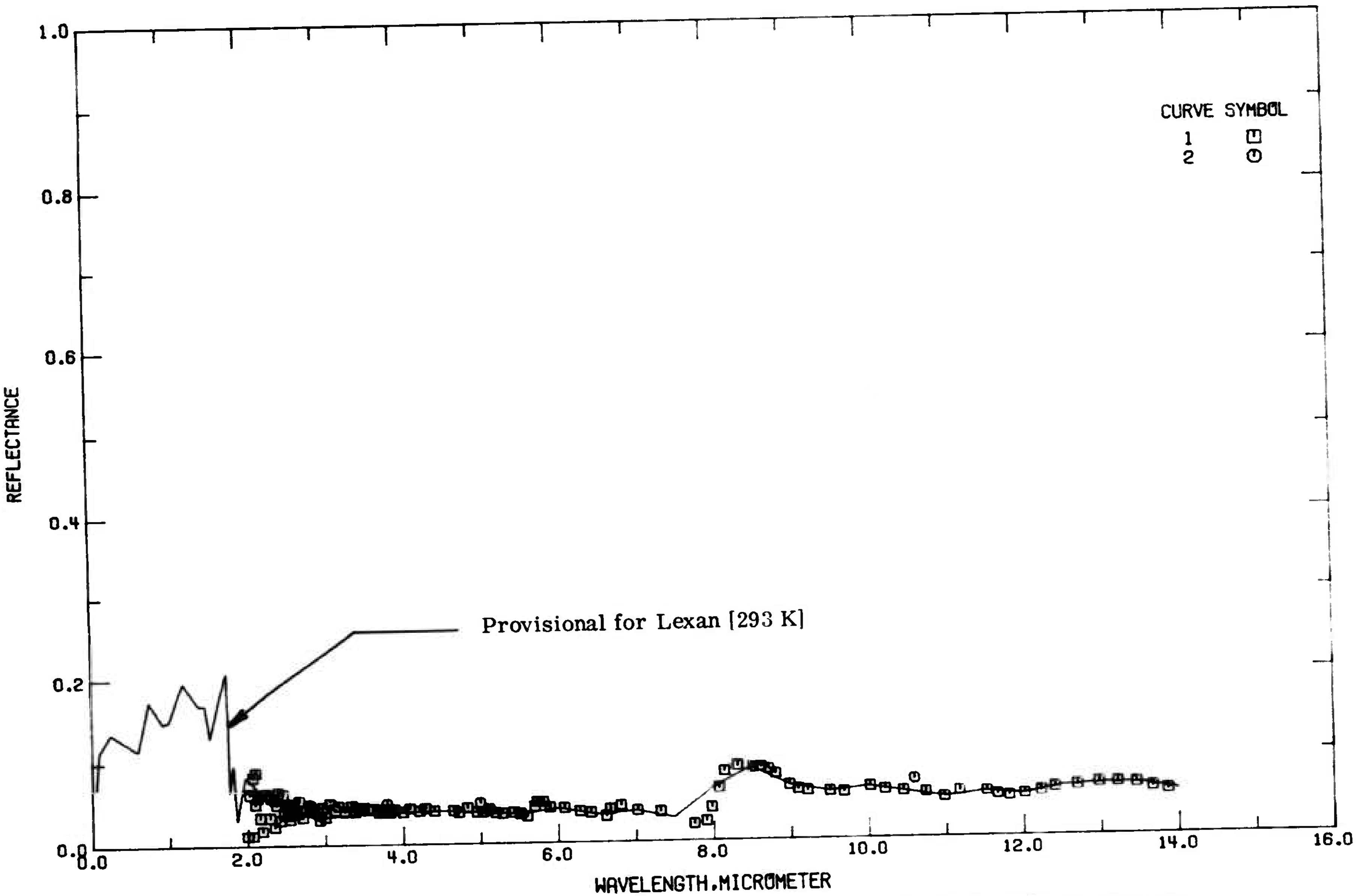


FIGURE 17-4. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE).

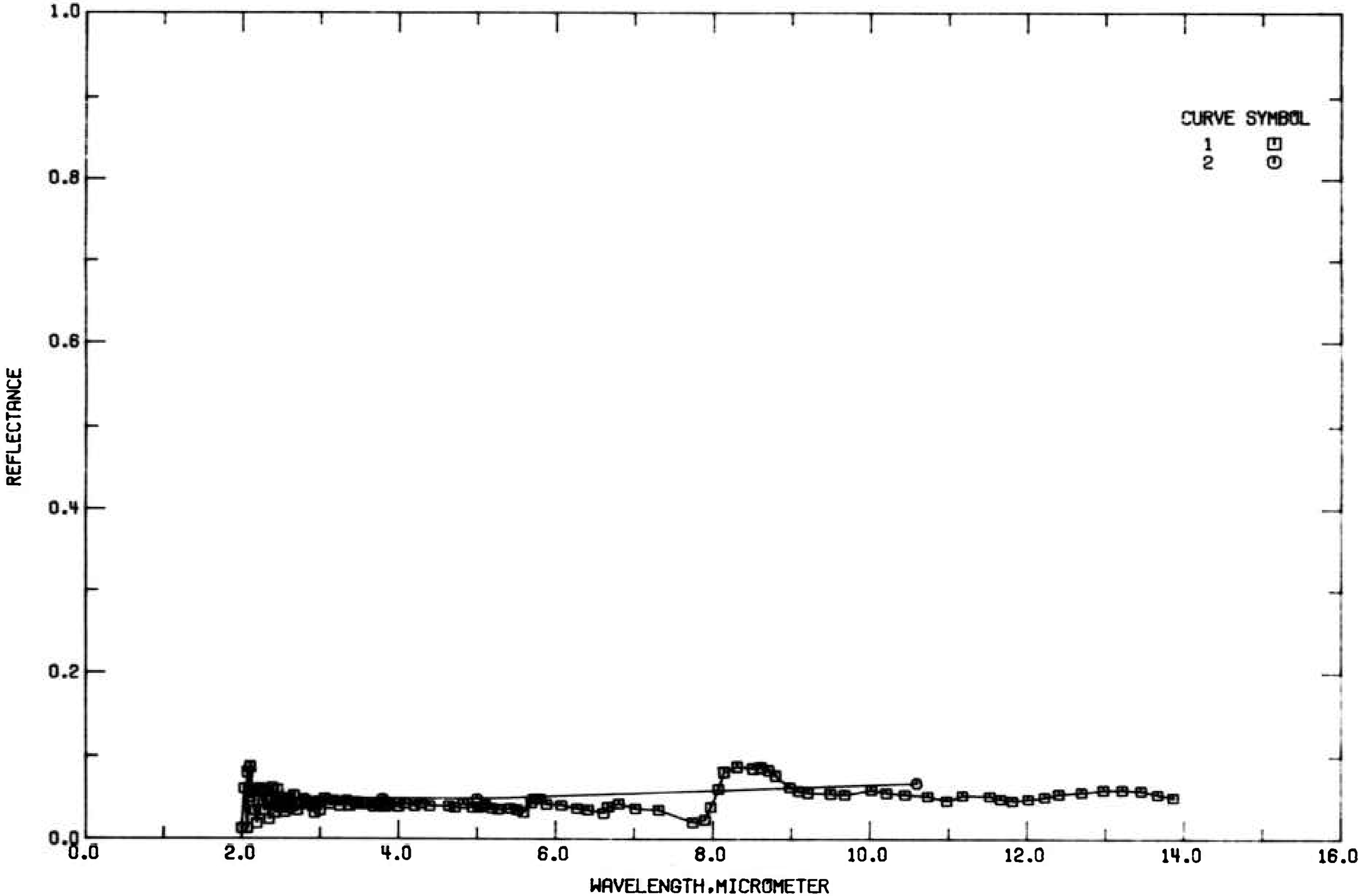


FIGURE 17-5. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE).

TABLE 17-6. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF POLYCARBONATE PLASTICS (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1		Grimm, T.C., Linfored, R.M.F., Dillow, C.F., Spinak, S., and Mills, J.P.	1972	2-15	293	Lexan Sample N-1	One in. diameter disc sample with thickness 290 mil.; reflectance was measured by utilizing a Dune Associate ellipsoidal-mirror reflectometer; θ=15°.
2		Grimm, T.C., et al.	1972	2-15	293	Lexan Sample N-1	The above specimen except θ=45°.

TABLE 17-7. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ	λ	ρ
CURVE 1		CURVE 1(CONT.)		CURVE 1(CONT.)		CURVE 2(CONT.)	
T = 293.		3.38	0.041	7.98	0.040	10.6	0.07
2.00	0.013	3.44	0.046	8.08	0.063		
2.03	0.063	3.46	0.044	8.15	0.083		
2.07	0.013	3.49	0.046	8.32	0.089		
2.07	0.082	3.55	0.043	8.52	0.087		
2.10	0.051	3.61	0.044	8.62	0.088		
2.11	0.088	3.69	0.040	8.72	0.085		
2.13	0.059	3.75	0.043	8.81	0.079		
2.16	0.035	3.83	0.040	8.99	0.065		
2.19	0.019	3.89	0.043	9.10	0.060		
2.23	0.063	4.00	0.040	9.22	0.058		
2.29	0.035	4.09	0.044	9.51	0.057		
2.30	0.059	4.21	0.041	9.69	0.056		
2.35	0.024	4.29	0.044	10.03	0.062		
2.37	0.050	4.40	0.041	10.22	0.058		
2.39	0.064	4.55	0.041	10.46	0.056		
2.42	0.032	4.72	0.039	10.75	0.054		
2.46	0.062	4.83	0.044	10.99	0.048		
2.47	0.040	4.95	0.039	11.19	0.055		
2.50	0.051	5.03	0.039	11.54	0.054		
2.52	0.038	5.11	0.042	11.68	0.050		
2.55	0.051	5.19	0.038	11.83	0.048		
2.55	0.033	5.28	0.037	12.03	0.050		
2.59	0.051	5.43	0.038	12.24	0.053		
2.62	0.040	5.51	0.036	12.42	0.057		
2.67	0.055	5.60	0.033	12.71	0.059		
2.68	0.043	5.70	0.045	12.99	0.062		
2.71	0.035	5.73	0.050	13.23	0.062		
2.75	0.043	5.81	0.050	13.47	0.061		
2.81	0.048	5.89	0.043	13.68	0.056		
2.83	0.044	6.08	0.042	13.88	0.052		
2.90	0.041	6.28	0.038	14.56	0.052		
2.93	0.032	6.42	0.036	14.68	0.054		
2.97	0.047	6.62	0.032				
3.00	0.035	6.67	0.040	CURVE 2			
3.06	0.051	6.81	0.044	T = 293.			
3.13	0.043	7.02	0.038				
3.17	0.048	7.32	0.036	2.8	0.05		
3.25	0.041	7.75	0.021	3.8	0.05		
3.34	0.048	7.91	0.024	5.0	0.05		

d. Normal Spectral Absorptance (Wavelength Dependence)

There is no data of absorptance available for bulk polycarbonate plastics. Only Fujikura and Ishikawa [T77102] have measured the absorptive power of thin films with thickness of 18 μm and 118 μm at 300 K. The absorptance data was obtained by dividing the absorptive power with the black body radiation power. According to Eq. (4.17-5), the absorptance is strongly dependent on the thickness of the sample for thin films. However, for the bulk materials, in the wavelength region $\lambda > 4$ μm,

$$\alpha(\lambda) \cong (1-R) \tag{4.17-9}$$

which is independent of the thickness, and the material becomes opaque. By using Eqs. (4.17-5, 4.17-6, and 4.17-7), the absorptance can be calculated as equal to the emittance. The calculated results are for a sample with thickness 4 mm at 293 K which are shown in Table 17-8 and Figure 17-6 together with the experimental data of thin films. The estimated uncertainty is about $\pm 20\%$.

TABLE 17-8. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α
THICKNESS 4MM		THICKNESS 4MM	
T = 293		T = 293 (CONT.)	
0.60	0.12	12.50	0.940
0.75	0.05	13.00	0.931
0.92	0.05	13.50	0.940
1.00	0.05	14.00	0.949
1.19	0.35	14.50	0.969
1.34	0.10	15.00	0.943
1.39	0.16		
1.47	0.07		
1.63	0.60		
1.65	0.77		
1.69	0.72		
1.75	0.33		
1.78	0.37		
1.83	0.43		
1.87	0.46		
1.98	0.32		
2.00	0.41		
2.50	0.94		
2.80	0.95		
3.00	0.92		
3.80	0.953		
4.00	0.951		
4.50	0.960		
5.00	0.962		
5.50	0.965		
6.00	0.959		
6.50	0.967		
7.00	0.963		
7.50	0.972		
8.00	0.933		
8.50	0.914		
9.00	0.936		
9.50	0.944		
10.00	0.939		
10.60	0.946		
11.00	0.953		
11.50	0.947		
12.00	0.951		
12.50	0.951		

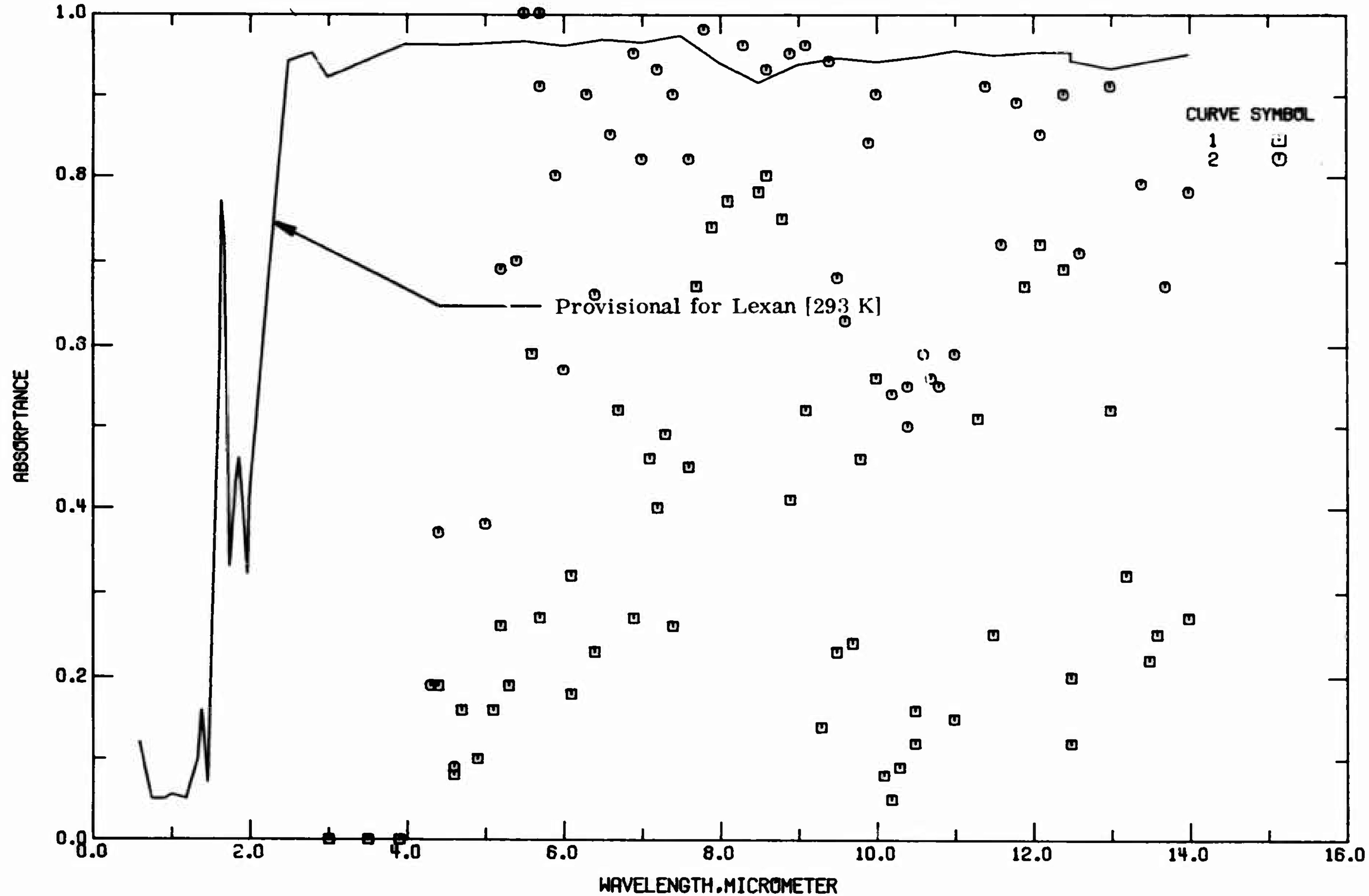


FIGURE 17-6. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE).

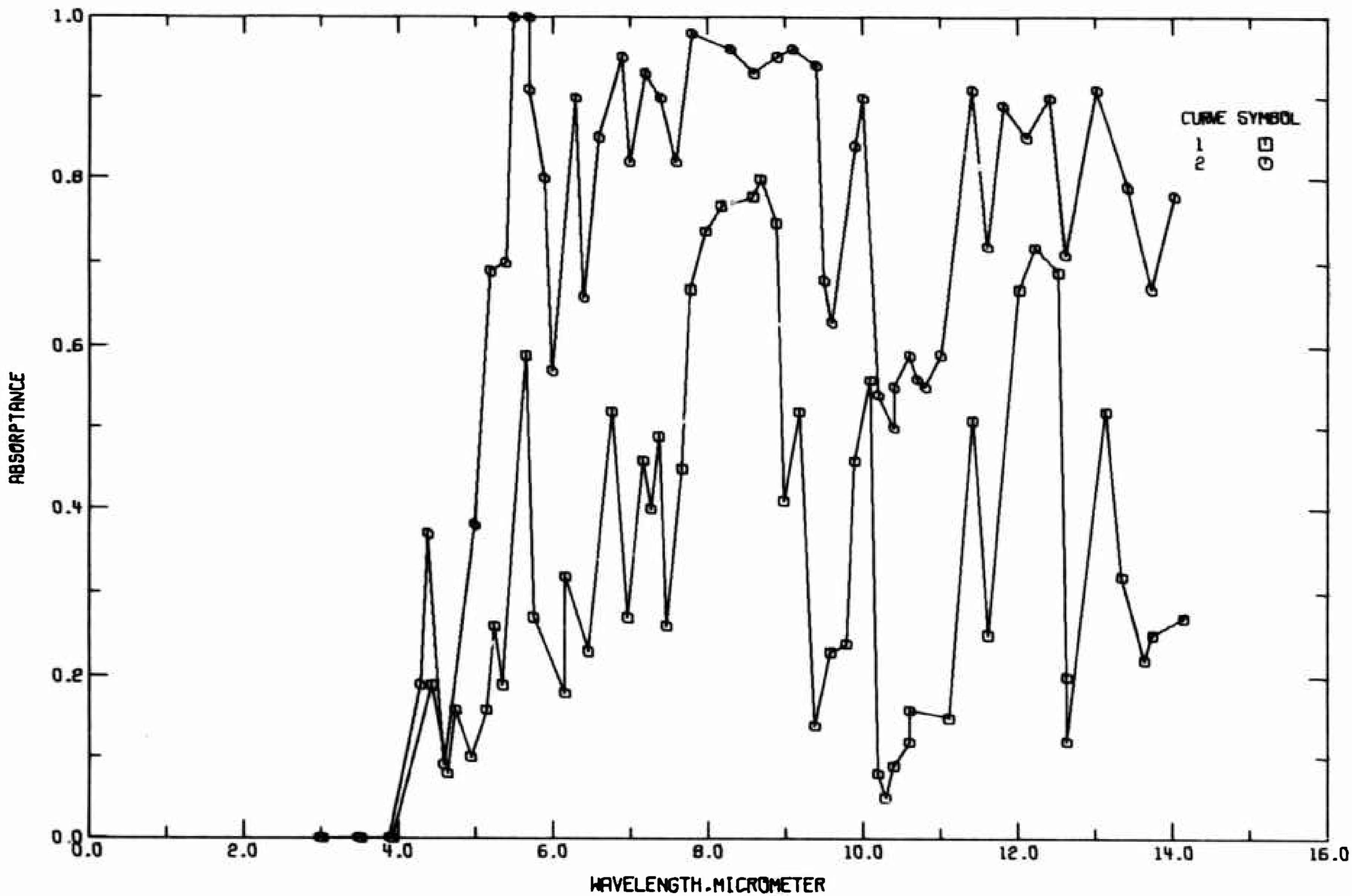


FIGURE 17-7. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE).

TABLE 17-9. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF POLYCARBONATE PLASTICS (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, µm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T77102	Fujikura, Y. and Ishikawa, K.	1968	2.5-50	300		Polycarbonate film; thickness 18 µm; absorptive power data were extracted from the figure; $\theta \sim 0°$.
2	T77102	Fujikura, Y. and Ishikawa, K.	1968	2.5-50	300		Polycarbonate film; thickness 118 µm; absorptive power data were extracted from the figure; $\theta \sim 0°$.

TABLE 17-10. EXPERIMENTAL SPECTRAL ABSORPTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α	λ	α	λ	α
CURVE 1		CURVE 1(CONT.)		CURVE 2		CURVE 2(CONT.)		CURVE 2(CONT.)	
T = 300.		10.50	0.16	T = 300.		11.40	0.91	41.00	0.23
3.00	0.00	11.00	0.15	3.00	0.000	11.60	0.72	45.20	0.35
3.50	0.00	11.30	0.51	3.50	0.00	11.80	0.89	50.00	0.00
3.90	0.00	11.50	0.25	3.90	0.00	12.10	0.85		
4.40	0.19	11.90	0.67	4.30	0.19	12.40	0.90		
4.60	0.08	12.10	0.72	4.40	0.37	12.60	0.71		
4.70	0.16	12.40	0.69	4.50	0.09	13.00	0.91		
4.90	0.10	12.50	0.20	5.00	0.38	13.40	0.79		
5.10	0.16	12.50	0.12	5.20	0.69	13.70	0.67		
5.20	0.26	13.00	0.52	5.40	0.70	14.00	0.78		
5.30	0.19	13.20	0.32	5.50	1.00	14.70	0.31		
5.60	0.59	13.50	0.22	5.70	1.00	15.30	0.20		
5.70	0.27	13.60	0.25	5.70	0.91	15.70	0.37		
6.10	0.18	14.00	0.27	5.90	0.80	16.00	0.25		
6.10	0.32	14.40	0.09	6.00	0.57	16.50	0.44		
6.40	0.23	14.90	0.07	6.30	0.90	16.90	0.67		
6.70	0.52	15.20	0.07	6.40	0.66	17.50	0.91		
6.90	0.27	15.40	0.05	6.60	0.85	18.20	0.94		
7.10	0.46	15.60	0.05	6.90	0.95	18.60	0.81		
7.20	0.40	16.00	0.00	7.00	0.82	18.90	0.55		
7.30	0.49	16.40	0.00	7.20	0.93	19.40	0.52		
7.40	0.26	16.80	0.10	7.40	0.90	20.50	0.51		
7.60	0.45	17.10	0.24	7.60	0.82	21.10	0.37		
7.70	0.67	17.50	0.36	7.80	0.98	21.90	0.24		
7.90	0.74	17.80	0.60	8.30	0.96	22.40	0.25		
8.10	0.77	18.10	0.65	8.60	0.93	23.00	0.40		
8.50	0.78	18.50	0.35	8.90	0.95	23.40	0.49		
8.50	0.80	19.30	0.15	9.10	0.96	24.00	0.55		
8.80	0.75	19.80	0.12	9.40	0.94	24.50	0.70		
8.90	0.41	20.00	0.04	9.50	0.68	25.00	0.74		
9.10	0.52	21.00	0.05	9.60	0.63	26.70	0.65		
9.30	0.14	22.40	0.10	9.90	0.84	28.30	0.56		
9.50	0.23	23.40	0.11	10.00	0.90	29.50	0.48		
9.70	0.24	24.30	0.16	10.20	0.54	31.00	0.41		
9.80	0.46	24.90	0.24	10.40	0.50	32.00	0.45		
10.00	0.56	28.00	0.33	10.40	0.55	32.80	0.34		
10.10	0.08	29.10	0.33	10.60	0.59	35.00	0.39		
10.20	0.05			10.70	0.56	36.60	0.25		
10.30	0.09			10.80	0.55	37.40	0.27		
10.50	0.12			11.00	0.59	39.30	0.38		

e. Normal Spectral Transmittance (Wavelength Dependence)

There are 16 sets of experimental data available for the transmittance of polycarbonate plastics as listed in Table 17-13. Of these, 5 sets were measured on thin film samples which are shown in Figure 17-5. They represent reasonably consistent results with each other. The major absorption peaks near $\lambda = 3.4$, 5.6, 6.6, 8.1, 8.2, 8.6, 9.8, and 12 μm are observed.

As we have mentioned in d., the bulk polycarbonate materials become opaque above $\lambda = 4$ μm. At the visible and near infrared region it transmits about 80-90%. Above 1.7 μm the transmittance becomes very strongly dependent on the thickness of the sample. Therefore, the recommended values of transmittance for a sample with thickness of 4 mm at 293 K were derived based on the works of Cloud [T54891, curve 4], Acitelli [T40338, curve 7], and Progelhof, et al. [T77125, curve 16]. The values are shown in Table 17-11 and in Figure 17-8 with the experimental data.

The recommended values which are for polished samples are estimated with an uncertainty of about ±20%.

TABLE 17-11. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ
THICKNESS 4MM		THICKNESS 4MM	
T = 293		T = 293 (CONT.)	
0.35	0.35	2.60	0.07
0.37	0.57	2.62	0.08
0.38	0.57	2.65	0.06
0.40	0.66	2.70	0.00
0.50	0.70	2.80	0.00
0.60	0.77	2.84	0.00
0.70	0.84	2.90	0.05
0.75	0.78	2.92	0.06
0.80	0.89	3.00	0.04
0.90	0.87	3.20	0.00
0.92	0.80	3.80	0.007
1.00	0.84	3.88	0.030
1.19	0.76	3.92	0.002
1.30	0.81	3.93	0.013
1.34	0.73	4.00	0.015
1.37	0.66	4.02	0.013
1.39	0.67	4.10	0.0
1.46	0.72	5.0	0.0
1.47	0.76	6.0	0.0
1.50	0.80	7.0	0.0
1.53	0.80	8.0	0.0
1.55	0.79	9.0	0.0
1.59	0.70	10.0	0.0
1.62	0.56	10.6	0.0
1.65	0.06	11.0	0.0
1.69	0.11	12.0	0.0
1.74	0.36	13.0	0.0
1.75	0.43	14.0	0.0
1.78	0.57	15.0	0.0
1.83	0.56		
1.87	0.54		
1.90	0.48		
1.95	0.50		
1.98	0.60		
2.00	0.56		
2.18	0.07		
2.21	0.17		
2.30	0.31		
2.50	0.01		

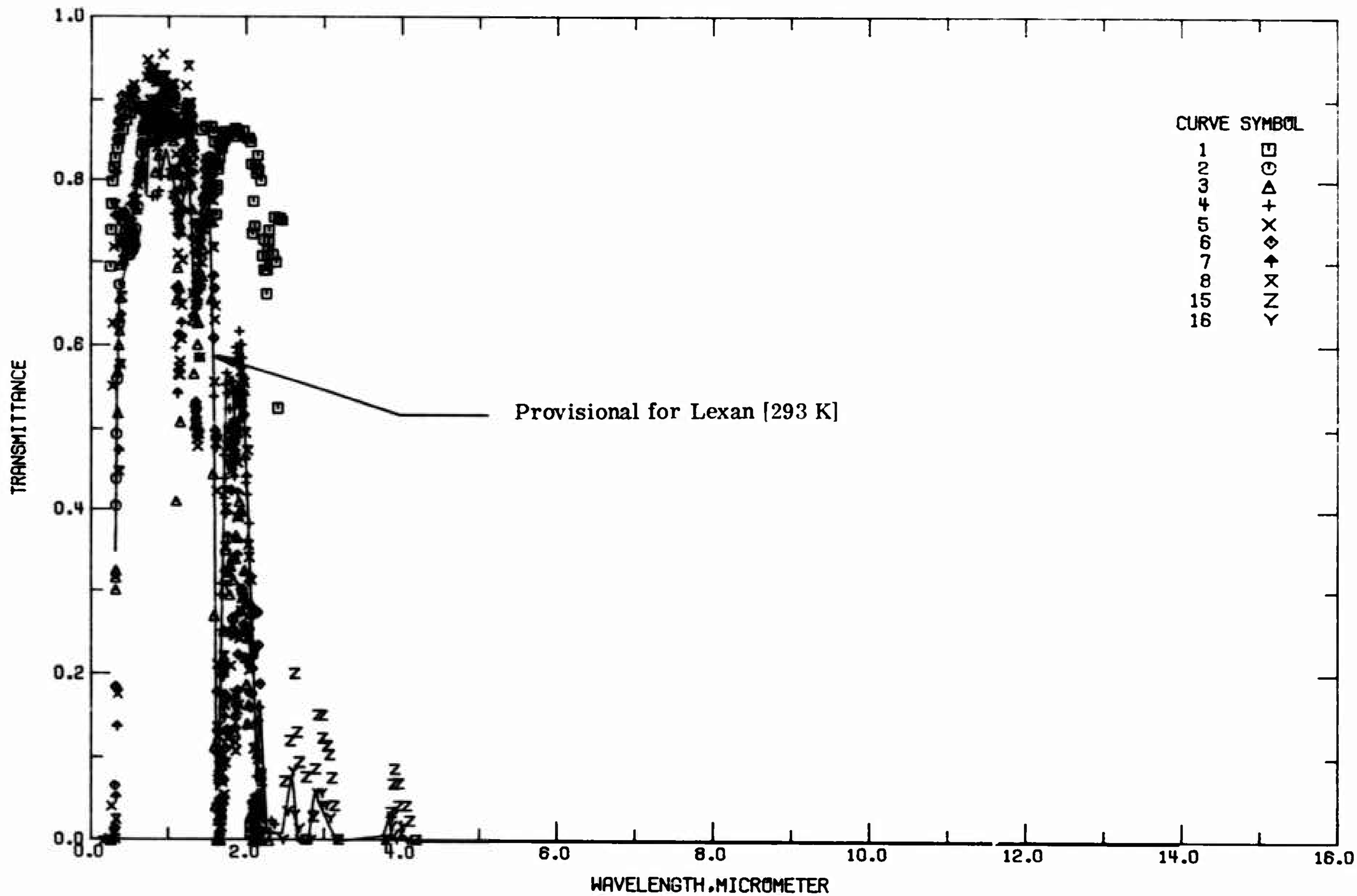


FIGURE 17-8. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE).

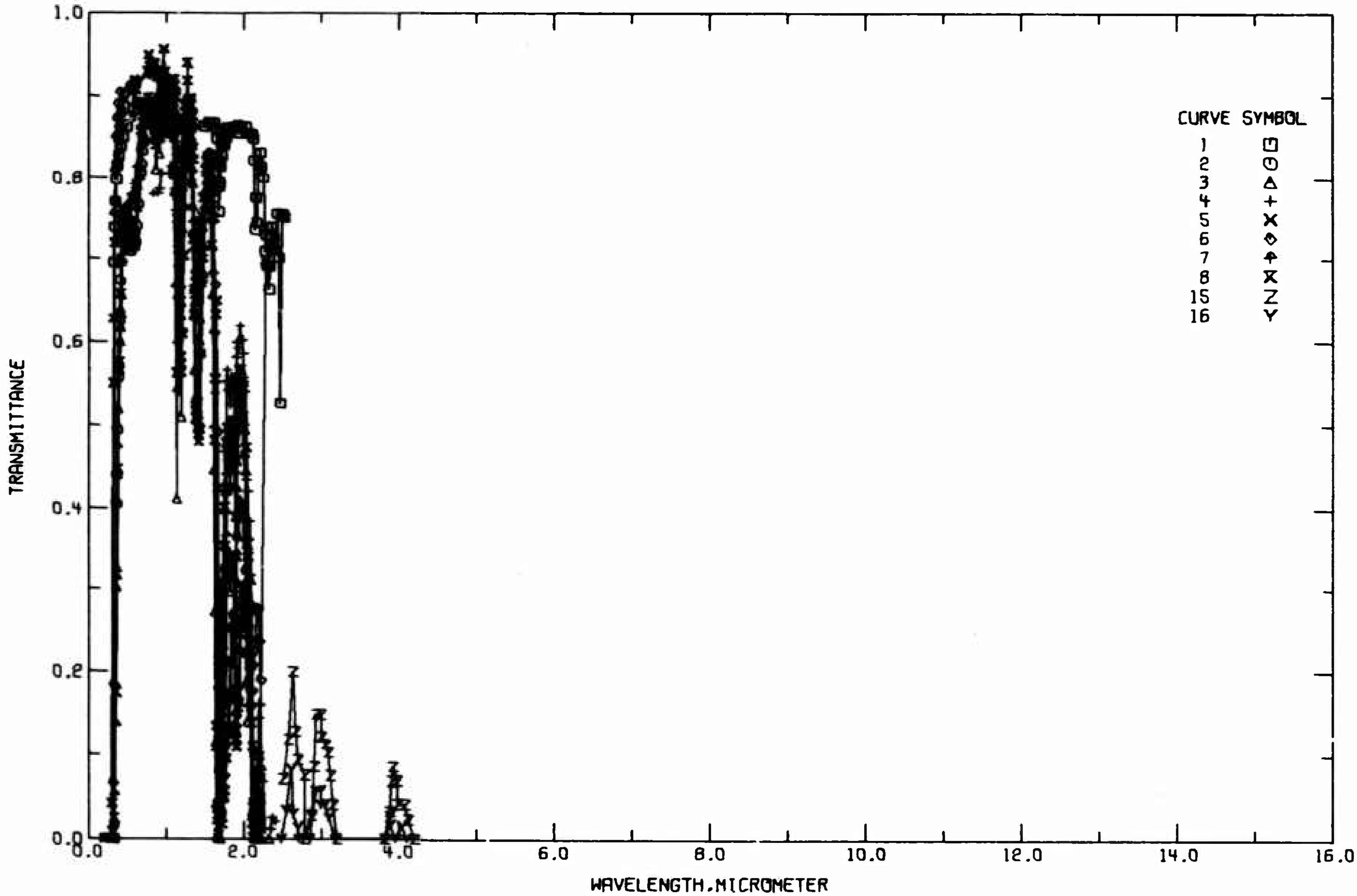


FIGURE 17-9. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE).

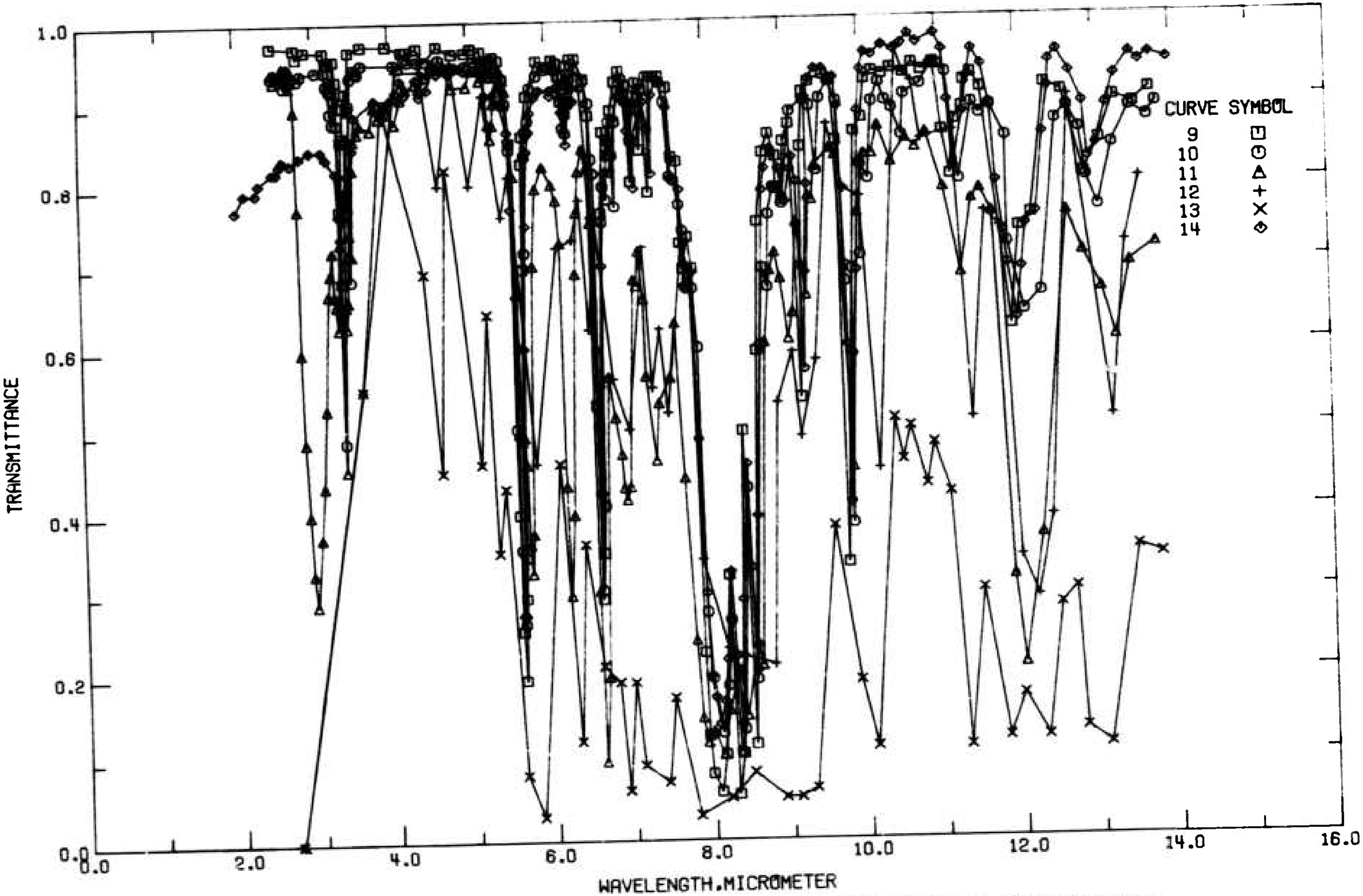


FIGURE 17-10. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF POLYCARBONATE PLASTICS THIN FILMS (WAVELENGTH DEPENDENCE).

TABLE 17-12. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF POLYCARBONATE PLASTICS (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T29424	Mobay Chemical Co.	1962	0.2-2.5	293	"Merlon" 100 ASTM D1003-59T	5 mil. thickness film; refractive index 1.5847; it absorbs essentially all light in the ultraviolet region (up to 2750 A), it transmits between 80-90% in the visible region (4000 to 7500 A) and 90% in the infrared wavelength range (8500-1100 A); the slight absorption of light in 3600 to 5000 A range gives natural Merlon the light straw-colored hue.
2	T57841	Cloud, G.	1970	0.3-2.3	293	Merlon	9.5 mm thickness unannealed sample; Perkin-Elmer model 137-BT spectrometer and Bausch and Lomb Pectronic is colorimeter was utilized to measure the transmission spectra; reported error 5%.
3	T57841	Cloud, G.	1970	0.3-0.9	293	Merlon	9.4 mm thickness annealed sample (at 154 C for 100 hr); Perkin-Elmer model 137-BT spectrometer and Bausch and Lomb Petronic is colorimeter was utilized to measure the transmission spectra; reported error 5%.
4	T57841	Cloud, G.	1970	0.8-2.3	293	Lexan	4.27 mm thickness sample; Perkin-Elmer model 137-BT spectrometer and Bausch and Lomb Petronic is colorimeter was utilized to measure the transmission spectra; reported error 5%.
5	T40338	Acitelli, M.A., Cumby, W.L., and Nujckas, A.A.	1966	0.2-2.2	296	Poly(allyl diglycol carbonate)	7.2 mm thickness disc, approx. 50 mm in diameter; Cary Spectrophoton model 14 was used in measurements.
6	T40338	Acitelli, M.A., et al.	1966	0.2-2.2	296	Poly(allyl diglycol carbonate)	The above specimen after 100 standard fade hr in solarization.
7	T40338	Acitelli, M.A., et al.	1966	0.2-2.2	296	Polycarbonate "Lexan"	6.15 mm thickness disc approximately 50 mm in diameter; Cary Spectrophotometer was used in measurements.
8	T40338	Acitelli, M.A., et al.	1966	0.2-2.2	296	Polycarbonate "Lexan"	The above specimen after 100 standard fade hr in solarization.
9	T76795	Stimler, S.S. and Kagarise, R.E.	1966	2.5-25	~293	K-1 Resin	Film specimen was obtained from Eastman Chemical Products; a Beckman IR-12 model spectrophotometer was used to obtain the spectra; data were extracted from the figure; θ~0°.
10	T76795	Stimler, S.S. and Kagarise, R.E.	1966	2.5-25	~293	Merlon M-50	Film specimen was obtained from Mobay Chemical Co.; other specifications similar to the above specimen.
11	T76798	Lara, M.O.	1967	2.5-25	~293	Lexan	The specimen was condensed pyrolyzate on potassium bromide or sodium chloride; a Beckman IR-9 double beamed, prism-grating infrared spectrophotometer was used to obtain the spectra; data were extracted from the figures; θ~0°.
12	T77102	Fujikura, Y. and Ishikawa, K.	1968	3-35	300		Polycarbonate film; thickness 18 μm; penetrating power data were extracted from the figure.
13	T77102	Fujikura, Y. and Ishikawa, K.	1968	3-35	300		Polycarbonate film; thickness 118 μm; penetrating power data were extracted from the figure.
14	T77125	Progelhof, R.C., Franey, J., and Haas, T.W.	1971	2-15	~293		Polycarbonate film was obtained from General Electrical Co.; thickness, 40 μm; data were extracted from the figure.
15	T77125	Progelhof, R.C., et al.	1971	2.5-4.19	~293		Cast sheet, thickness 0.0625 in.; data were extracted from the figure; θ~0°.
16	T77125	Progelhof, R.C., et al.	1971	2.48-4.09	~293		Cast sheet, thickness 0.1268 in.; data were extracted from the figure; θ~0°.

TABLE 17-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 1		CURVE 1(CONT.)		CURVE 1(CONT.)		CURVE 2(CONT.)		CURVE 3(CONT.)		CURVE 3(CONT.)	
T = 293.		1.662	0.819	2.478	0.754	0.842	0.874	0.651	0.804	1.346	0.631
0.286	0.000	1.673	0.814	2.500	0.751	0.855	0.857	0.662	0.814	1.358	0.566
0.286	0.695	1.686	0.828			0.864	0.857	0.683	0.846	1.369	0.506
0.292	0.739	1.692	0.844	CURVE 2		0.872	0.866	0.694	0.846	1.398	0.513
0.302	0.771	1.710	0.846	T = 293.		0.884	0.874	0.708	0.868	1.408	0.602
0.314	0.799	1.719	0.841			0.891	0.868	0.719	0.872	1.413	0.628
0.335	0.816	1.737	0.857	0.353	0.406	0.898	0.873	0.747	0.873	1.421	0.628
0.348	0.828	1.751	0.851	0.356	0.440	0.904	0.868	0.756	0.883	1.441	0.672
0.375	0.840	1.768	0.862	0.363	0.495	0.914	0.868	0.784	0.884	1.464	0.683
0.400	0.852	1.871	0.862	0.373	0.559	0.925	0.889	0.796	0.872	1.474	0.716
0.444	0.864	1.888	0.856	0.390	0.626	0.949	0.901	0.802	0.889	1.492	0.765
0.455	0.876	1.902	0.866	0.402	0.673	0.957	0.893	0.812	0.882	1.517	0.797
0.535	0.884	1.913	0.856	0.422	0.728			0.830	0.849	1.535	0.797
0.583	0.892	1.926	0.863	0.436	0.750	CURVE 3		0.843	0.849	1.554	0.778
0.636	0.892	2.000	0.863	0.458	0.759	T = 293.		0.863	0.810	1.572	0.749
0.665	0.890	2.052	0.854	0.480	0.737			0.877	0.850	1.591	0.656
0.743	0.892	2.075	0.854	0.483	0.725	0.349	0.302	0.888	0.850	1.605	0.446
0.759	0.887	2.092	0.849	0.497	0.721	0.351	0.317	0.902	0.831	1.615	0.271
0.844	0.877	2.104	0.821	0.508	0.709	0.354	0.326	0.927	0.866	1.628	0.114
0.883	0.882	2.119	0.735	0.536	0.709	0.377	0.520	0.988	0.866	1.633	0.042
0.944	0.880	2.132	0.775	0.548	0.720	0.382	0.568	1.005	0.856	1.654	0.000
0.964	0.872	2.146	0.744	0.562	0.715	0.395	0.601	1.010	0.856	1.694	0.000
1.038	0.872	2.155	0.821	0.577	0.715	0.402	0.618	1.029	0.868	1.702	0.075
1.097	0.868	2.169	0.809	0.584	0.721	0.406	0.634	1.079	0.868	1.715	0.092
1.125	0.861	2.185	0.832	0.593	0.721	0.412	0.657	1.094	0.850	1.726	0.049
1.141	0.866	2.196	0.814	0.614	0.741	0.412	0.697	1.104	0.783	1.735	0.212
1.173	0.862	2.226	0.800	0.640	0.768	0.422	0.725	1.130	0.412	1.743	0.253
1.198	0.865	2.249	0.708	0.664	0.807	0.430	0.725	1.142	0.655	1.754	0.177
1.237	0.866	2.265	0.728	0.678	0.818	0.441	0.751	1.152	0.694	1.771	0.351
1.251	0.861	2.274	0.691	0.684	0.834	0.460	0.761	1.162	0.672	1.792	0.324
1.286	0.863	2.300	0.662	0.697	0.847	0.469	0.761	1.182	0.510	1.802	0.325
1.452	0.864	2.306	0.691	0.706	0.848	0.502	0.719	1.191	0.738	1.816	0.296
1.517	0.868	2.318	0.716	0.722	0.868	0.523	0.719	1.197	0.790	1.830	0.331
1.586	0.868	2.330	0.726	0.730	0.866	0.537	0.730	1.204	0.824	1.847	0.340
1.610	0.861	2.335	0.739	0.741	0.866	0.560	0.730	1.241	0.869	1.868	0.314
1.624	0.849	2.382	0.710	0.756	0.875	0.566	0.724	1.268	0.869	1.887	0.131
1.639	0.823	2.403	0.755	0.765	0.873	0.578	0.737	1.293	0.847	1.896	0.340
1.650	0.758	2.424	0.701	0.778	0.872	0.588	0.733	1.308	0.812	1.903	0.369
1.656	0.789	2.442	0.526	0.803	0.882	0.600	0.738	1.322	0.796	1.919	0.366
1.662	0.794	2.463	0.753	0.828	0.882	0.622	0.764	1.335	0.765	1.928	0.393

TABLE 17-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE	3(CONT.)	CURVE	4(CONT.)	CURVE	4(CONT.)	CURVE	5(CONT.)	CURVE	5(CONT.)	CURVE	5(CONT.)
1.943	0.411	1.367	0.662	1.996	0.553	0.569	0.908	1.436	0.586	2.114	0.010
1.958	0.393	1.391	0.666	2.014	0.541	0.584	0.919	1.466	0.700	2.123	0.020
1.975	0.399	1.415	0.726	2.031	0.435	0.598	0.907	1.494	0.775	2.132	0.044
2.012	0.326	1.421	0.723	2.044	0.421	0.754	0.928	1.524	0.827	2.150	0.051
2.022	0.221	1.437	0.742	2.053	0.363	0.765	0.948	1.581	0.829	2.174	0.105
2.036	0.169	1.463	0.746	2.069	0.384	0.784	0.934	1.596	0.817	2.188	0.399
2.048	0.141	1.484	0.778	2.090	0.268	0.817	0.934	1.604	0.790	2.200	0.049
2.066	0.164	1.512	0.803	2.109	0.047	0.827	0.938	1.611	0.749		
2.098	0.032	1.547	0.603	2.125	0.011	0.845	0.938	1.627	0.556	CURVE 6	
2.118	0.000	1.586	0.751	2.151	0.020	0.878	0.922	1.634	0.632	T = 296.	
2.176	0.000	1.602	0.683	2.165	0.079	0.901	0.893	1.642	0.648		
2.195	0.031	1.618	0.539	2.178	0.058	0.952	0.925	1.661	0.425	0.200	0.000
2.212	0.031	1.652	0.045	2.187	0.145	0.963	0.955	1.666	0.213	0.294	0.000
2.225	0.000	1.662	0.000	2.190	0.162	0.973	0.928	1.674	0.126	0.306	0.012
2.325	0.000	1.670	0.080	2.207	0.161	0.998	0.908	1.684	0.080	0.313	0.066
		1.678	0.071	2.223	0.082	1.027	0.898	1.701	0.031	0.322	0.164
CURVE 4		1.686	0.096	2.237	0.068	1.069	0.920	1.714	0.017	0.328	0.755
T = 293.		1.705	0.296	2.258	0.011	1.100	0.920	1.738	0.050	0.335	0.809
		1.715	0.310	2.339	0.011	1.118	0.899	1.751	0.057	0.346	0.850
0.830	0.780	1.726	0.254	2.360	0.025	1.134	0.833	1.764	0.095	0.360	0.873
0.889	0.781	1.747	0.469	2.400	0.021	1.155	0.711	1.796	0.124	0.375	0.890
0.912	0.787	1.754	0.416			1.173	0.573	1.834	0.211	0.402	0.904
0.934	0.805	1.760	0.441	CURVE 5		1.181	0.564	1.854	0.251	0.533	0.912
1.035	0.805	1.768	0.553	T = 296.		1.186	0.582	1.865	0.260	0.543	0.908
1.058	0.814	1.779	0.567			1.199	0.609	1.877	0.247	0.556	0.914
1.091	0.814	1.792	0.543	0.200	0.000	1.217	0.703	1.891	0.178	0.764	0.925
1.101	0.786	1.808	0.543	0.284	0.000	1.238	0.831	1.894	0.119	0.782	0.932
1.112	0.759	1.818	0.525	0.296	0.042	1.258	0.879	1.901	0.109	0.809	0.934
1.131	0.598	1.834	0.557	0.313	0.551	1.266	0.918	1.918	0.158	0.848	0.934
1.147	0.735	1.861	0.557	0.318	0.627	1.273	0.893	1.930	0.164	0.872	0.923
1.151	0.751	1.875	0.543	0.333	0.719	1.296	0.897	1.949	0.244	0.896	0.899
1.165	0.732	1.884	0.443	0.346	0.770	1.314	0.897	1.970	0.277	0.914	0.899
1.178	0.664	1.891	0.475	0.357	0.814	1.331	0.876	1.984	0.292	0.934	0.906
1.189	0.764	1.898	0.582	0.376	0.849	1.341	0.823	1.995	0.292	0.957	0.921
1.200	0.802	1.907	0.599	0.393	0.867	1.359	0.662	2.007	0.284	0.967	0.910
1.248	0.819	1.921	0.592	0.413	0.881	1.381	0.517	2.017	0.253	0.985	0.914
1.285	0.819	1.949	0.618	0.455	0.896	1.392	0.520	2.048	0.245	1.005	0.899
1.314	0.797	1.962	0.602	0.539	0.904	1.402	0.489	2.075	0.206	1.025	0.899
1.329	0.789	1.975	0.602	0.554	0.912	1.411	0.480	2.087	0.139	1.065	0.917
1.344	0.731	1.987	0.586	0.561	0.908	1.421	0.495	2.103	0.019	1.089	0.917

TABLE 17-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE	6(CONT.)	CURVE	6(CONT.)	CURVE	7(CONT.)	CURVE	7(CONT.)	CURVE	7(CONT.)	CURVE	8
1.108	0.908	1.744	0.075	0.378	0.573	1.258	0.855	1.764	0.366	T = 296.	
1.119	0.877	1.750	0.098	0.394	0.635	1.264	0.892	1.777	0.484	0.320	0.000
1.141	0.773	1.766	0.112	0.415	0.695	1.264	0.868	1.788	0.458	0.330	0.024
1.165	0.614	1.790	0.134	0.438	0.728	1.282	0.849	1.808	0.456	0.350	0.175
1.176	0.570	1.840	0.251	0.455	0.751	1.328	0.808	1.816	0.424	0.373	0.447
1.196	0.612	1.857	0.268	0.471	0.751	1.340	0.745	1.825	0.450	0.388	0.575
1.223	0.754	1.875	0.250	0.492	0.738	1.343	0.710	1.830	0.476	0.410	0.656
1.237	0.829	1.884	0.172	0.510	0.744	1.359	0.643	1.840	0.466	0.430	0.700
1.259	0.890	1.893	0.136	0.522	0.768	1.370	0.662	1.850	0.481	0.452	0.728
1.265	0.877	1.898	0.149	0.555	0.778	1.380	0.647	1.859	0.468	0.468	0.737
1.285	0.896	1.904	0.165	0.592	0.792	1.385	0.668	1.875	0.461	0.486	0.738
1.306	0.896	1.924	0.182	0.620	0.813	1.396	0.677	1.889	0.343	0.501	0.728
1.323	0.884	1.933	0.225	0.663	0.860	1.405	0.715	1.897	0.421	0.529	0.745
1.334	0.843	1.954	0.275	0.711	0.877	1.416	0.705	1.908	0.508	0.556	0.774
1.346	0.730	1.969	0.303	0.755	0.887	1.434	0.734	1.925	0.497	0.595	0.774
1.359	0.636	1.986	0.303	0.774	0.875	1.456	0.734	1.938	0.524	0.618	0.792
1.376	0.528	1.998	0.291	0.836	0.871	1.486	0.781	1.945	0.532	0.671	0.859
1.387	0.532	2.005	0.261	0.853	0.845	1.512	0.803	1.952	0.527	0.692	0.876
1.396	0.503	2.023	0.252	0.866	0.866	1.558	0.788	1.958	0.513	0.716	0.885
1.404	0.492	2.064	0.216	0.879	0.866	1.575	0.756	1.977	0.516	0.757	0.885
1.415	0.498	2.077	0.179	0.869	0.851	1.593	0.682	1.997	0.463	0.768	0.898
1.431	0.586	2.090	0.161	0.905	0.870	1.607	0.497	2.016	0.441	0.784	0.869
1.451	0.672	2.103	0.178	0.918	0.874	1.614	0.477	2.031	0.319	0.847	0.863
1.486	0.777	2.111	0.208	0.949	0.874	1.634	0.105	2.044	0.310	0.862	0.840
1.504	0.814	2.122	0.224	0.959	0.889	1.646	0.018	2.048	0.253	0.883	0.863
1.517	0.825	2.142	0.231	0.976	0.870	1.653	0.000	2.055	0.237	0.907	0.851
1.543	0.825	2.160	0.275	0.997	0.857	1.659	0.009	2.069	0.280	0.912	0.868
1.551	0.831	2.180	0.275	1.015	0.865	1.662	0.035	2.084	0.218	0.927	0.878
1.572	0.831	2.196	0.236	1.069	0.865	1.673	0.023	2.102	0.042	0.954	0.881
1.585	0.816	2.213	0.190	1.085	0.852	1.677	0.036	2.116	0.000	0.966	0.927
1.599	0.781			1.100	0.812	1.687	0.047	2.155	0.003	0.985	0.888
1.617	0.610	CURVE	7	1.110	0.667	1.697	0.197	2.160	0.025	1.010	0.879
1.629	0.669	T = 296.		1.121	0.541	1.708	0.196	2.174	0.013	1.058	0.893
1.649	0.493			1.132	0.665	1.714	0.209	2.184	0.055	1.075	0.893
1.662	0.180	0.200	0.000	1.142	0.755	1.718	0.159	2.190	0.075	1.101	0.877
1.667	0.133	0.300	0.000	1.156	0.739	1.724	0.147	2.200	0.043	1.110	0.803
1.676	0.106	0.316	0.014	1.174	0.626	1.728	0.175			1.129	0.563
1.691	0.051	0.328	0.052	1.188	0.803	1.734	0.323			1.146	0.748
1.704	0.031	0.342	0.136	1.201	0.837	1.742	0.394			1.150	0.784
1.723	0.053	0.364	0.473	1.247	0.863	1.753	0.306			1.181	0.647

TABLE 17-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE CF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE	8(CONT.)	CURVE	8(CONT.)	CURVE	9	CURVE	9(CONT.)	CURVE	9(CONT.)	CURVE	9(CONT.)
1.192	0.823	1.771	0.423	T = 296.		5.62	0.193	7.67	0.827	10.83	0.933
1.207	0.866	1.774	0.479	2.50	0.971	5.64	0.293	7.69	0.724	10.99	0.942
1.238	0.889	1.781	0.497	2.80	0.969	5.68	0.694	7.72	0.692	11.09	0.860
1.261	0.889	1.794	0.478	2.82	0.958	5.69	0.826	7.78	0.732	11.19	0.806
1.268	0.939	1.812	0.478	2.93	0.966	5.71	0.859	7.84	0.693	11.25	0.873
1.274	0.893	1.823	0.449	3.18	0.964	5.78	0.908	7.91	0.225	11.35	0.888
1.285	0.871	1.830	0.471	3.21	0.951	5.92	0.951	7.94	0.125	11.38	0.920
1.295	0.871	1.837	0.501	3.24	0.951	6.05	0.944	7.97	0.079	11.47	0.929
1.313	0.843	1.847	0.489	3.26	0.925	6.12	0.952	8.08	0.057	11.59	0.911
1.333	0.831	1.857	0.505	3.29	0.917	6.17	0.948	8.14	0.102	11.93	0.620
1.349	0.723	1.865	0.490	3.31	0.954	6.20	0.932	8.23	0.320	12.05	0.740
1.367	0.656	1.875	0.494	3.33	0.929	6.22	0.902	8.31	0.054	12.21	0.756
1.375	0.679	1.893	0.389	3.35	0.770	6.27	0.892	8.37	0.103	12.41	0.915
1.385	0.657	1.902	0.458	3.37	0.680	6.30	0.922	8.45	0.497	12.63	0.906
1.390	0.680	1.907	0.527	3.39	0.856	6.30	0.945	8.54	0.114	12.90	0.806
1.402	0.691	1.913	0.542	3.41	0.861	6.35	0.953	8.64	0.592	13.11	0.847
1.411	0.731	1.922	0.532	3.42	0.898	6.41	0.953	8.68	0.750	13.30	0.898
1.424	0.720	1.932	0.544	3.45	0.915	6.51	0.928	8.77	0.836	13.55	0.890
1.438	0.745	1.942	0.567	3.48	0.895	6.55	0.884	8.85	0.859	13.76	0.907
1.465	0.751	1.952	0.567	3.50	0.965	6.60	0.529	8.94	0.831	14.12	0.885
1.477	0.774	1.967	0.547	3.66	0.971	6.62	0.291	8.94	0.791	14.27	0.915
1.513	0.811	1.980	0.553	3.99	0.971	6.65	0.349	9.02	0.776	14.47	0.927
1.540	0.811	2.001	0.495	4.19	0.964	6.69	0.763	9.04	0.849	15.38	0.932
1.561	0.799	2.026	0.473	4.23	0.956	6.73	0.864	9.12	0.871	15.58	0.923
1.576	0.774	2.037	0.355	4.25	0.964	6.81	0.835	9.22	0.535	16.05	0.931
1.590	0.716	2.048	0.340	4.38	0.968	6.84	0.890	9.26	0.842	16.72	0.919
1.620	0.432	2.058	0.274	4.48	0.952	6.91	0.924	9.30	0.909	17.27	0.885
1.641	0.135	2.076	0.312	4.64	0.970	6.96	0.937	9.38	0.921	17.54	0.763
1.654	0.028	2.108	0.110	4.83	0.961	7.03	0.920	9.57	0.929	17.83	0.732
1.665	0.000	2.118	0.031	5.00	0.962	7.08	0.802	9.66	0.922	18.21	0.837
1.674	0.041	2.131	0.000	5.08	0.967	7.11	0.892	9.72	0.849	18.48	0.870
1.686	0.030	2.162	0.000	5.20	0.963	7.14	0.907	9.78	0.334	19.01	0.890
1.698	0.070	2.172	0.042	5.26	0.941	7.18	0.890	9.95	0.860	20.04	0.889
1.704	0.204	2.185	0.025	5.29	0.952	7.20	0.841	10.05	0.877	20.37	0.886
1.714	0.206	2.190	0.037	5.36	0.956	7.24	0.915	10.10	0.923	21.83	0.886
1.720	0.221	2.192	0.077	5.42	0.952	7.30	0.789	10.20	0.933	22.57	0.861
1.730	0.161	2.200	0.080	5.48	0.928	7.35	0.930	10.33	0.929	23.58	0.808
1.744	0.353	2.281	0.698	5.54	0.851	7.46	0.930	10.44	0.936	25.00	0.749
1.749	0.401			5.58	0.397	7.56	0.917	10.60	0.930		
1.762	0.323			5.59	0.253	7.60	0.832	10.72	0.942		

TABLE 17-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 10		CURVE 10(CONT.)		CURVE 10(CONT.)		CURVE 10(CONT.)		CURVE 10(CONT.)		CURVE 11(CONT.)	
T = 293.		5.49	0.900	7.06	0.898	10.00	0.766	17.57	0.803	3.31	0.624
2.50	0.934	5.52	0.843	7.08	0.852	10.02	0.820	17.89	0.817	3.33	0.728
2.65	0.932	5.56	0.502	7.15	0.923	10.12	0.802	18.28	0.868	3.37	0.454
2.66	0.923	5.59	0.353	7.23	0.913	10.18	0.896	18.59	0.782	3.40	0.652
2.68	0.930	5.61	0.262	7.29	0.930	10.28	0.919	19.12	0.815	3.41	0.626
2.82	0.931	5.65	0.344	7.46	0.923	10.35	0.897	19.69	0.893	3.43	0.657
2.87	0.937	5.69	0.714	7.52	0.899	10.44	0.888	20.24	0.911	3.44	0.715
3.06	0.942	5.71	0.835	7.57	0.808	10.56	0.855	20.79	0.902	3.46	0.740
3.18	0.941	5.74	0.865	7.62	0.803	10.59	0.904	21.32	0.910	3.49	0.713
3.20	0.924	5.77	0.879	7.68	0.773	10.81	0.916	22.68	0.694	3.51	0.822
3.24	0.919	5.81	0.918	7.72	0.740	10.95	0.939	23.53	0.864	3.53	0.857
3.25	0.891	5.90	0.933	7.75	0.668	11.04	0.939	25.00	0.772	3.59	0.866
3.28	0.878	6.00	0.940	7.83	0.668	11.14	0.930			3.62	0.876
3.30	0.908	6.12	0.940	7.89	0.597	11.29	0.800	CURVE 11		3.75	0.870
3.33	0.877	6.19	0.932	7.94	0.274	11.47	0.893	T = 293.		3.81	0.895
3.37	0.468	6.21	0.917	7.99	0.194	11.56	0.880			3.86	0.884
3.40	0.704	6.22	0.869	8.10	0.128	11.70	0.890	2.50	0.939	3.93	0.890
3.44	0.857	6.25	0.863	8.19	0.184	11.89	0.852	2.52	0.929	3.96	0.900
3.47	0.682	6.25	0.886	8.24	0.264	11.89	0.720	2.54	0.940	4.07	0.877
3.49	0.901	6.31	0.901	8.34	0.105	12.09	0.637	2.62	0.940	4.16	0.907
3.51	0.933	6.32	0.928	8.39	0.132	12.32	0.659	2.64	0.947	4.22	0.920
3.56	0.944	6.39	0.939	8.48	0.428	12.53	0.872	2.70	0.947	4.39	0.920
3.58	0.939	6.49	0.926	8.56	0.192	12.69	0.887	2.72	0.923	4.47	0.934
3.61	0.938	6.55	0.899	8.69	0.598	12.84	0.861	2.73	0.945	4.56	0.950
3.66	0.949	6.57	0.831	8.73	0.692	12.92	0.802	2.76	0.931	4.72	0.943
4.07	0.949	6.59	0.813	8.80	0.669	13.07	0.765	2.78	0.694	4.81	0.920
4.13	0.944	6.61	0.503	8.83	0.759	13.26	0.841	2.80	0.771	5.00	0.921
4.26	0.952	6.62	0.303	8.90	0.793	13.50	0.886	2.82	0.595	5.06	0.941
4.38	0.952	6.67	0.408	8.94	0.793	13.72	0.874	2.85	0.488	5.14	0.941
4.47	0.933	6.69	0.752	9.00	0.772	13.83	0.890	2.88	0.399	5.17	0.928
4.66	0.954	6.71	0.797	9.12	0.886	14.04	0.897	2.92	0.326	5.21	0.935
4.84	0.945	6.75	0.780	9.30	0.899	14.35	0.889	2.95	0.287	5.27	0.875
5.00	0.946	6.78	0.854	9.38	0.892	14.56	0.918	3.03	0.370	5.29	0.857
5.10	0.952	6.81	0.876	9.45	0.813	15.06	0.927	3.08	0.434	5.32	0.874
5.20	0.952	6.84	0.835	9.51	0.901	15.58	0.927	3.13	0.528	5.34	0.901
5.29	0.933	6.86	0.771	9.62	0.921	15.87	0.916	3.18	0.665	5.40	0.922
5.34	0.939	6.88	0.876	9.73	0.897	16.18	0.931	3.20	0.690	5.47	0.899
5.38	0.933	6.93	0.914	9.79	0.674	16.86	0.908	3.23	0.718	5.49	0.915
5.40	0.938	6.98	0.928	9.85	0.383	17.09	0.923	3.26	0.664	5.56	0.811
5.46	0.931	7.03	0.951	9.89	0.689	17.30	0.913	3.28	0.653	5.60	0.600

TABLE 17-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 11 (CONT.)		CURVE 11 (CONT.)		CURVE 11 (CONT.)		CURVE 12 (CONT.)		CURVE 12 (CONT.)		CURVE 13 (CONT.)	
5.63	0.488	7.79	0.240	12.66	0.759	5.00	0.80	12.40	0.39	3.90	0.98
5.66	0.492	7.85	0.146	12.85	0.708	5.20	0.91	12.70	0.90	4.40	0.69
5.68	0.459	7.91	0.117	13.09	0.663	5.40	0.76	13.20	0.51	4.60	0.45
5.69	0.360	7.99	0.130	13.26	0.605	5.50	0.81	13.40	0.72	4.70	0.82
5.72	0.324	8.11	0.102	13.46	0.694	5.80	0.46	13.60	0.80	5.10	0.46
5.74	0.373	8.20	0.155	13.79	0.717	6.10	0.72	14.20	0.76	5.20	0.64
5.79	0.698	8.34	0.203	14.10	0.744	6.30	0.73	14.70	0.94	5.30	0.35
5.84	0.795	8.42	0.148	14.25	0.692	6.40	0.78	15.40	0.96	5.40	0.43
5.94	0.823	8.58	0.236	14.43	0.698	6.50	0.62	15.70	0.99	5.60	0.08
6.05	0.800	8.64	0.209	14.62	0.674	6.60	0.75	15.90	0.99	5.80	0.03
6.10	0.780	8.75	0.602	14.84	0.733	6.80	0.56	16.20	1.00	6.10	0.46
6.14	0.726	8.83	0.689	15.08	0.747	7.00	0.50	16.70	1.00	6.30	0.12
6.19	0.432	8.90	0.711	15.87	0.703	7.20	0.72	17.60	0.65	6.40	0.36
6.21	0.296	8.96	0.679	16.13	0.730	7.30	0.55	17.80	0.43	6.60	0.21
6.27	0.397	9.06	0.606	16.39	0.699	7.40	0.62	18.10	0.38	6.80	0.19
6.33	0.688	9.12	0.638	16.75	0.709	7.50	0.52	18.40	0.50	6.90	0.06
6.36	0.764	9.17	0.749	17.27	0.669	7.70	0.72	18.60	0.68	7.00	0.19
6.40	0.816	9.29	0.658	17.57	0.606	7.80	0.69	19.50	0.88	7.10	0.09
6.45	0.843	9.35	0.782	17.73	0.494	7.90	0.34	19.80	0.91	7.40	0.07
6.50	0.819	9.39	0.777	18.35	0.484	8.20	0.23	20.10	0.99	7.50	0.17
6.53	0.751	9.43	0.818	18.45	0.587	8.40	0.22	21.10	1.00	7.80	0.03
6.57	0.302	9.63	0.840	18.73	0.600	8.80	0.21	21.60	1.00	8.20	0.05
6.61	0.095	9.70	0.832	19.31	0.700	8.90	0.53	22.10	0.97	8.50	0.08
6.67	0.196	9.86	0.452	19.88	0.631	9.10	0.59	23.50	0.94	8.90	0.05
6.74	0.563	9.97	0.760	20.24	0.686	9.20	0.49	25.00	0.83	9.10	0.05
6.82	0.515	10.07	0.833	20.66	0.703	9.40	0.58	26.90	0.79	9.30	0.06
6.90	0.471	10.17	0.833	20.92	0.740	9.60	0.87	28.90	0.77	9.60	0.38
6.92	0.430	10.26	0.867	21.83	0.755	9.80	0.79	33.80	1.00	9.90	0.19
6.95	0.415	10.42	0.823	24.04	0.720	10.00	0.78	35.00	1.00	10.10	0.11
7.00	0.431	10.60	0.851	25.00	0.759	10.20	0.45	37.10	1.00	10.40	0.51
7.07	0.680	10.73	0.840			10.50	0.96	39.60	0.99	10.50	0.46
7.11	0.672	10.87	0.658	CURVE 12		10.60	0.93	42.20	0.97	10.60	0.50
7.14	0.714	11.07	0.791	T = 300.		10.70	0.92	46.00	1.00	10.80	0.43
7.20	0.656	11.29	0.633			10.80	0.85	48.00	1.00	10.90	0.48
7.22	0.563	11.44	0.776	2.70	0.00	11.20	0.86	50.00	1.00	11.10	0.42
7.34	0.463	11.55	0.789	3.60	0.55	11.40	0.51			11.30	0.11
7.38	0.531	11.70	0.759	4.10	0.94	11.60	0.76	CURVE 13		11.50	0.30
7.53	0.561	11.90	0.316	4.40	0.94	11.80	0.74	T = 300.		11.80	0.12
7.59	0.627	12.02	0.298	4.60	0.80	12.00	0.34			12.00	0.17
7.69	0.441	12.27	0.367	4.80	0.95	12.20	0.29	3.60	0.55	12.30	0.12

TABLE 17-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 13(CONT.)		CURVE 13(CONT.)		CURVE 14(CONT.)		CURVE 14(CONT.)		CURVE 14(CONT.)		CURVE 14(CONT.)	
12.50	0.28	47.90	0.88	4.72	0.943	6.81	0.814	9.19	0.800	12.13	0.743
12.70	0.30	50.00	0.84	4.79	0.937	6.88	0.881	9.22	0.694	12.27	0.758
12.80	0.13			4.86	0.943	6.93	0.906	9.26	0.569	12.37	0.856
13.10	0.11	CURVE 14		4.97	0.940	7.00	0.914	9.28	0.686	12.45	0.911
13.50	0.35	T = 293.		5.17	0.940	7.04	0.865	9.33	0.796	12.47	0.943
13.80	0.34			5.22	0.933	7.11	0.794	9.33	0.902	12.57	0.955
14.10	0.25	2.00	0.770	5.24	0.910	7.11	0.856	9.38	0.924	12.73	0.929
14.50	0.51	2.12	0.792	5.34	0.910	7.25	0.900	9.46	0.937	12.89	0.892
14.80	0.71	2.27	0.792	5.43	0.900	7.30	0.867	9.56	0.937	12.95	0.825
15.40	0.84	2.31	0.804	5.51	0.865	7.34	0.812	9.70	0.926	13.06	0.841
15.70	0.79	2.49	0.818	5.52	0.854	7.36	0.908	9.74	0.891	13.19	0.889
15.90	0.66	2.54	0.818	5.53	0.765	7.44	0.926	9.77	0.792	13.31	0.925
16.20	0.78	2.58	0.827	5.57	0.660	7.55	0.893	9.80	0.695	13.51	0.951
16.40	0.70	2.62	0.833	5.59	0.493	7.59	0.807	9.82	0.598	13.63	0.941
16.90	0.41	2.72	0.829	5.59	0.272	7.69	0.792	9.83	0.409	13.76	0.950
17.30	0.22	2.84	0.837	5.63	0.272	7.73	0.671	9.89	0.586	13.99	0.943
17.60	0.11	2.97	0.844	5.63	0.493	7.82	0.687	9.95	0.688	14.12	0.919
18.00	0.08	3.12	0.844	5.67	0.598	7.88	0.488	10.00	0.885	14.26	0.936
18.40	0.12	3.18	0.835	5.71	0.748	7.94	0.298	10.05	0.935	14.39	0.947
19.10	0.50	3.30	0.818	5.75	0.841	7.97	0.196	10.10	0.956	14.61	0.941
20.50	0.53	3.33	0.763	5.79	0.865	8.02	0.170	10.20	0.953	14.74	0.915
21.00	0.66	3.33	0.647	5.81	0.889	8.07	0.138	10.33	0.964	15.00	0.912
21.70	0.74	3.35	0.647	5.86	0.907	8.14	0.165	10.48	0.959		
22.10	0.81	3.35	0.735	5.93	0.915	8.18	0.216	10.58	0.966	CURVE 15	
22.60	0.80	3.39	0.762	6.07	0.915	8.25	0.325	10.67	0.977	T = 293.	
23.00	0.67	3.41	0.794	6.07	0.909	8.30	0.220	10.77	0.967		
23.60	0.54	3.45	0.797	6.16	0.919	8.36	0.138	11.00	0.977	2.50	0.071
24.10	0.51	3.45	0.815	6.21	0.889	8.40	0.289	11.10	0.958	2.57	0.119
24.50	0.36	3.52	0.846	6.26	0.849	8.49	0.457	11.16	0.896	2.63	0.200
25.10	0.31	3.56	0.886	6.30	0.896	8.52	0.329	11.22	0.816	2.66	0.129
28.30	0.51	3.82	0.906	6.36	0.902	8.57	0.203	11.36	0.883	2.69	0.094
29.30	0.60	4.03	0.906	6.35	0.918	8.61	0.393	11.41	0.924	2.78	0.076
30.60	0.68	4.10	0.915	6.45	0.918	8.69	0.592	11.48	0.958	2.78	0.000
31.90	0.73	4.16	0.929	6.55	0.758	8.75	0.790	11.60	0.939	2.87	0.028
33.00	0.81	4.21	0.912	6.60	0.595	8.79	0.817	11.70	0.890	2.90	0.086
35.00	0.82	4.36	0.930	6.61	0.423	8.87	0.840	11.76	0.798	2.93	0.150
37.10	0.82	4.40	0.910	6.64	0.423	8.97	0.816	11.84	0.735	2.99	0.150
39.50	0.76	4.50	0.918	6.64	0.552	9.05	0.775	11.89	0.694	2.99	0.122
41.60	0.91	4.57	0.942	6.68	0.697	9.12	0.815	12.00	0.628	3.05	0.113
45.80	0.75	4.63	0.937	6.74	0.814	9.14	0.830	12.07	0.689	3.08	0.103

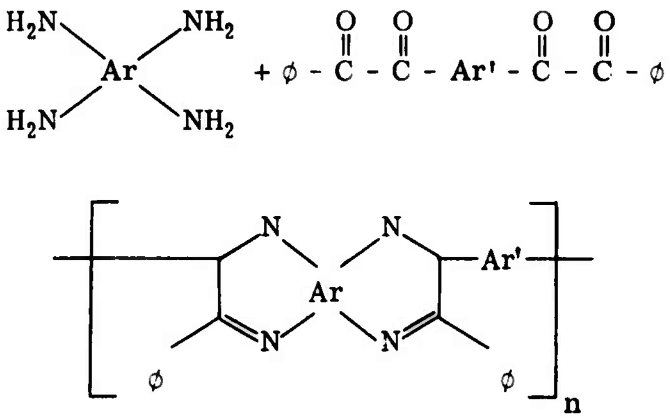
TABLE 17-13. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF POLYCARBONATE PLASTICS (WAVELENGTH DEPENDENCE) (CONTINUED)

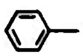
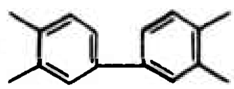
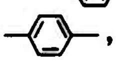
[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

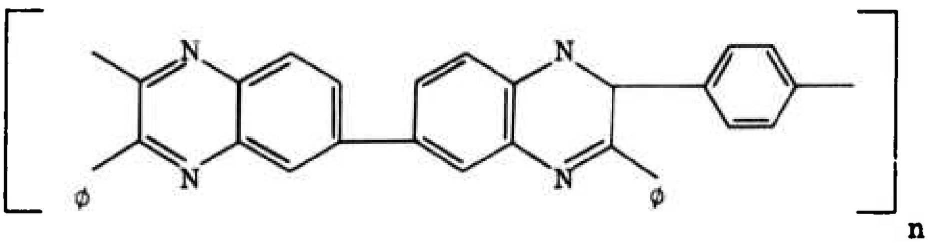
λ	τ
CURVE 15(CONT.)	
3.11	0.075
3.14	0.041
3.19	0.000
3.81	0.000
3.87	0.033
3.90	0.068
3.92	0.086
3.97	0.069
3.97	0.041
4.07	0.041
4.11	0.023
4.19	0.000
CURVE 16	
T = 293.	
2.48	0.000
2.48	0.000
2.54	0.034
2.61	0.083
2.63	0.030
2.69	0.014
2.70	0.000
2.84	0.000
2.87	0.027
2.92	0.057
2.98	0.057
2.98	0.041
3.04	0.041
3.09	0.026
3.17	0.000
3.62	0.000
3.84	0.024
3.88	0.017
3.94	0.000
4.03	0.016
4.09	0.000

4.18. Poly(phenylquinoxaline), PPQ

The preparation of soluble high molecular weight poly(phenylquinoxalines), PPQ, by the condensation of aromatic bis(o-diamines) with aromatic bisbenzils was first reported in 1967.

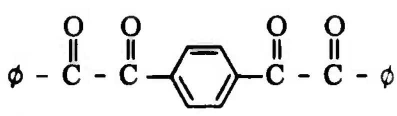


where ϕ =  and Ar, Ar' = aromatic typically, for PPQI Ar =  and Ar' = , hence PPQI is described by the formula:



UV data for homo- and copolymers exhibit a λ_{max} in the case of PPQI at 292 μm. Apparently the p-phenylene moiety and the phenyl group are forced out of the plane due to steric interaction, and therefore, are unable to participate significantly in resonance, for λ_{max} to appear at shorter wavelength.

The current interest in PPQ's is due to the high thermal stability and unusual ease of formation of these polymers. Formation is a one stage quantitative process at room temperature which yields completely cyclized, soluble polymers. Reaction of 1,4-di(phenylglyoxal) benzene



in excess in air yields a crosslinked polymer compared with the usual linear polymer when the reagents are used in stoichiometric amounts.

PPQ's are faintly yellow fibrous amorphous substances readily soluble in most organic solvents. Typical molecular weights are of the order of 330,000. PPQ polymers were shown to exhibit good solubility and processability as well as excellent thermal oxidative stability. However, IR spectra of PPQ demonstrates the ease of oxidation of the methylene bridges in those polymers containing this structural feature. It starts decomposition at 780 to 830 K.

The potential of PPQ for use as functional and structural resin in high temperature environment has been demonstrated.

PPQ specimens may be cured at 644 K and 1000 psi for four hours. The thermal linear expansion of the cured material increases gradually to the instability temperature of 578 K with the expansion at this point being 1.3% [T77908]. Above the instability temperature, PPQ first contracts, then expands slightly, then finally contracts severely above 756 K where degradation occurs.

The thermal conductivity of PPQ exhibits increasing values from 0.00293 W cm^{-1} K^{-1} at 340 K to 0.00317 W cm^{-1} K^{-1} at 533 K. Typical densities fall in the range 1.196 - 1.205 g cm^{-3}.

PPQ carbon fiber composites have been studied as potential re-entry vehicle (REV) materials.

No information on the thermal radiative properties of this material was uncovered from the search of literature. Consequently, no tabulation or recommendation of the thermal radiative properties of this material is possible at this time.

4.19. Silicone Resin

These organo-silicon oxide polymers may be resins, rubbers, or liquids. They are characterized by resistance to heat, oxidation, and weathering; water repellency; near independence of physical properties with temperature; and resistance to electrical breakdown. Their thermal degradation temperature is about 473 to 873 K.

Industrial uses include silicone release agents, lubricants, adhesives, laminating resins, electrical insulation, molding compounds, and additives. Trade names include Silastic, Polysil, Versilube, Dow Corning Silicone, etc.

In the United States, major companies producing silicones for industrial use include Dow Corning Corporation, General Electric Company, and Union Carbide Corporation.

For the purpose of aircraft design, the application of silicone resins may be classified in the following three ways:

(1) Silicone laminating resins - These are used primarily in bonding glass cloth to produce structural and electrical laminates. They are also used to bond asbestos paper and cloth. Silicone-glass laminates have excellent resistance to heat and heat aging.

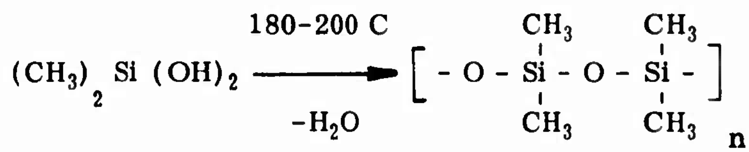
(2) Interlayer for laminates glass - Silastic Type K Interlayer serves as the center layer in safety glass windshield for supersonic aircraft.

(3) Silicone molding compounds - These are thermosetting materials that can be formed by either compression or transfer molding techniques. For high-impact, glass fiber-filled silicone molding compounds, the heat distortion temperature is about 755 K. Parts molded from silicone molding compounds find use as both structural and dielectric materials in aircraft and missiles.

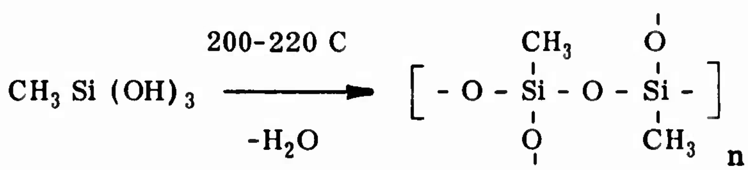
Several silicone resins have been considered for application in aerospace construction. Poly(dimethylsilanediol) with a melting point of 740 K has been considered for use as a matrix material for flexible windows and domes in manned spacecraft, although it has been suggested that it has insufficient tear resistance for this purpose. Polyphenyl silicone has been considered for use as a paint-like organic coating for spacecraft, designed to control emission and absorption of radiant energy. Silicone DC 808 has been considered for similar uses. Silicone XRG-2044 has been considered for use as a coating for solar cells. Owens-Illinois "Glass Resin 100" has been studied for possible use as a lightweight optical material for aerospace reconnaissance. Some elastomers

are used for oxygen hoses, space suits, and cabin seals. Silicone resins are also used as ablation shields for space ships.

Silicones consist of chains of alternate Si and O atoms. The chains are modified by various organic groups attached to Si, or by crosslinking. Silicone polymers are prepared by condensation of di- or trihydroxymethylsilanes.



Silicone rubber



Silicone resin

Uncured silicone resins are soluble in some organic liquids such as toluene, xylene, petroleum spirit, and n-butyl acetate. Cured silicone resins can be swollen by toluene and some other hydrocarbons, carbon tetrachloride, methyl chloride, acetone, methyl ethyl ketone, liquid ammonia, liquid sulphur dioxide, and glacial acetic acid. They may be decomposed by the attack of concentrated hydrochloric and sulphuric acids.

Silicone resins have density about 1.0-1.2 g cm^{-3}. Its refractive index is about 1.405-1.49, specific heat 0.36-0.37, thermal conductivity 0.00146 W cm^{-1} K^{-1}. Silicone resins that are flexible at room temperature have a brittleness temperature of 200 K or lower. The resins soften at temperatures from 300 K to above 470 K according to the degree of cure (cross-linkage). Prolonged heating causes gradual loss of weight by breakdown of volatile products, e.g., benzene and cyclic siloxanes from methylsiloxanes at 400-500 K. Its electrical resistivity at room temperature is about 3.10^{13} - 5.10^{15} Ω cm and dielectric constant is 2.75-2.85 from 60-10^6 HZ. Its dielectric strength is about 20-120 kV/mm at room temperature, 50% lower at 370 K, and 20-30% lower for wet film. The arc resistance of silicone resins is greater than that of the organic resins.

a. Normal Spectral Emittance (Wavelength Dependence)

There are six sets of experimental data available for the wavelength dependence of the normal spectral emittance of silicone resins as listed in Table 19-3 and shown in Fig. 19-2. Specimen characterization and measurement information for the data are

given in Table 19-2. Two data sets each are for "Pyrosin" heat resistant paint on aluminum plate at 473 and 673 K with brown, green, and beige color, respectively. In the wavelength region above $\lambda = 8\ \mu m$, there are very small differences among the values of emittance for different paint. However, in the shorter wavelength region, i.e., $\lambda < 8\ \mu m$, brown paint has the highest emittance value and beige paint has the lowest emittance value. Since the data are limited, as a consequence, only provisional values were reported here. The provisional values are listed in Table 19-1 and shown in Figure 19-1 for the green "Pyrosin" paint on aluminum plate at 473 K. The estimated uncertainty is within $\pm 30\%$.

TABLE 19-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF SILICONE RESIN (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
PYROSIN GREEN T = 473	
2.70	0.67
2.90	0.74
3.00	0.81
3.20	0.84
3.40	0.82
3.80	0.74
4.00	0.73
4.68	0.76
5.00	0.86
5.20	0.90
5.80	0.91
6.00	0.92
6.50	0.93
7.00	0.93
7.50	0.94
8.00	0.94
8.50	0.95
9.00	0.96
9.60	0.94
10.00	0.94
10.20	0.94
10.50	0.94
11.00	0.96
11.80	0.96
12.00	0.96
12.50	0.97
13.00	0.97
13.50	0.97
14.00	0.98
14.50	0.98
15.00	0.98

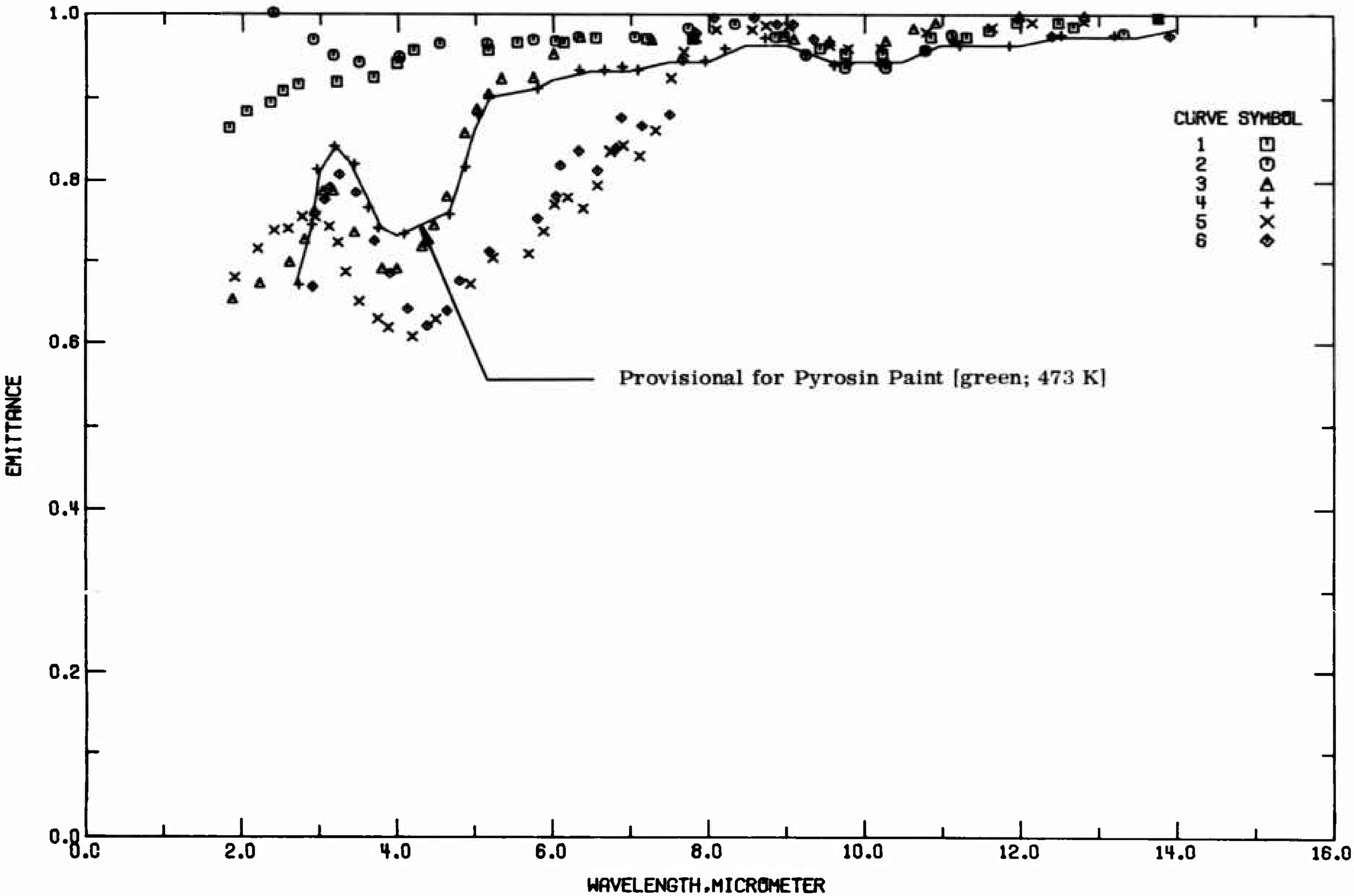


FIGURE 19-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF SILICONE RESIN COATING (WAVELENGTH DEPENDENCE).

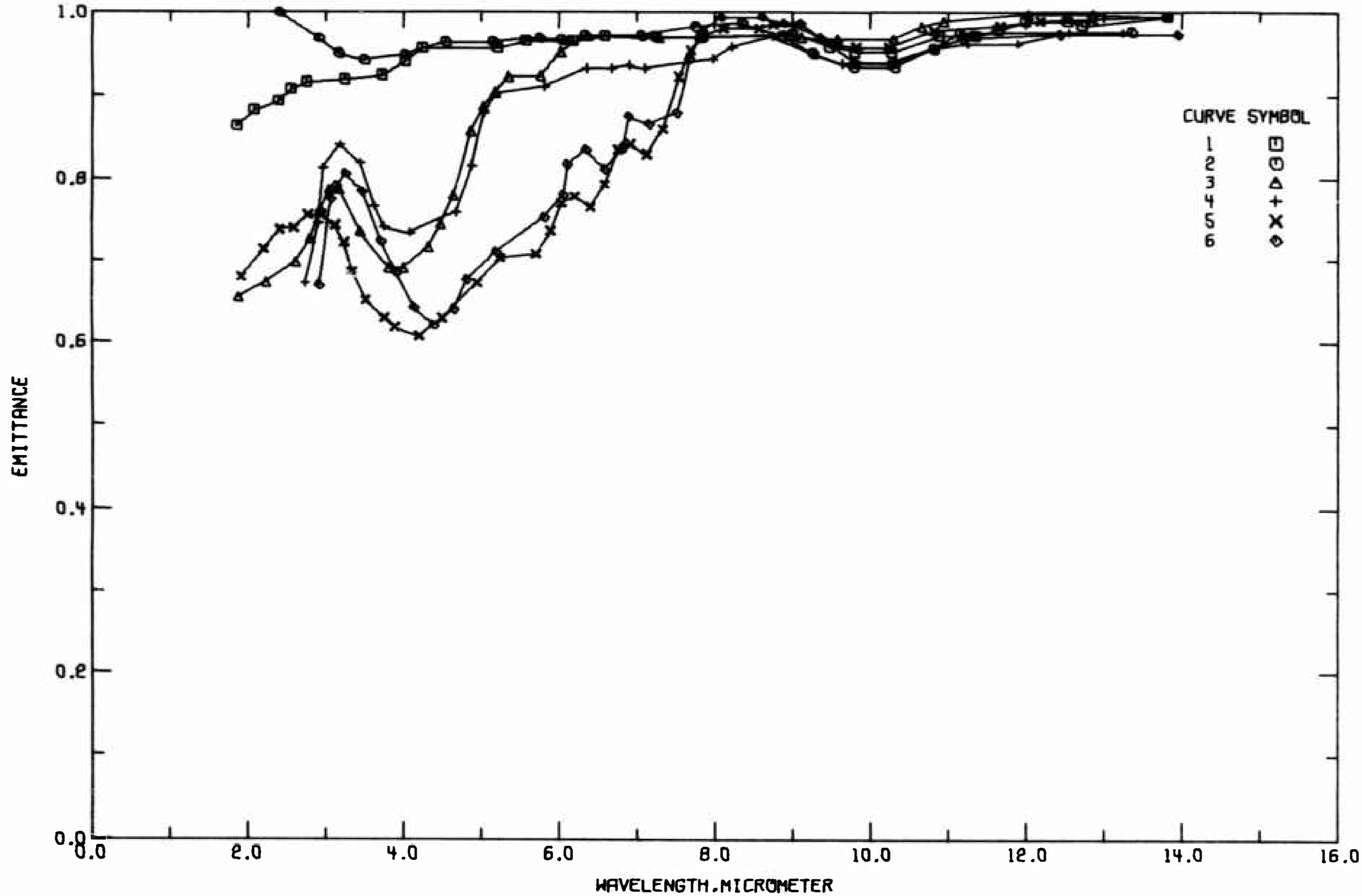


FIGURE 19-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICONE RESIN (WAVELENGTH DEPENDENCE).

TABLE 19-2. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF SILICONE RESIN COATING (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T71893	Kanayama, K.	1972	1-25	673	"Pyrosin"	Heat resisting paint with brown color was coated on aluminum plate; data were extracted from figure; $\theta \sim 0°$.
2	T71893	Kanayama, K.	1972	1-25	473	"Pyrosin"	Similar to the above specimen.
3	T71893	Kanayama, K.	1972	1-25	673	"Pyrosin"	Similar to the above specimen except paint with green color.
4	T71893	Kanayama, K.	1972	1-25	473	"Pyrosin"	Similar to the above specimen.
5	T71893	Kanayama, K.	1972	1-25	673	"Pyrosin"	Similar to the above specimen except paint with beige color.
6	T71893	Kanayama, K.	1972	1-25	473	"Pyrosin"	Similar to the above specimen.

TABLE 19-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 1	
T = 673.	
1.83	0.862
2.05	0.882
2.36	0.893
2.52	0.907
2.72	0.915
3.21	0.918
3.69	0.923
3.99	0.939
4.21	0.954
5.17	0.954
5.54	0.963
6.14	0.963
6.55	0.969
7.21	0.968
7.80	0.968
8.97	0.971
9.44	0.956
9.77	0.950
10.24	0.950
10.86	0.970
11.32	0.970
11.61	0.978
11.97	0.988
12.50	0.988
12.69	0.983
13.78	0.994
15.40	0.994
18.39	0.989
19.09	0.975
19.91	0.975
20.52	0.965
21.35	0.960
21.94	0.948
23.33	0.948
23.87	0.958
24.45	0.977
25.15	0.984

λ	ε
CURVE 2	
T = 473.	
2.40	1.000
2.91	0.967
3.17	0.948
3.50	0.940
4.02	0.946
4.54	0.962
5.15	0.962
5.75	0.967
6.03	0.965
6.33	0.970
7.05	0.970
7.74	0.981
8.34	0.986
8.86	0.970
9.25	0.949
9.75	0.934
10.26	0.934
10.79	0.954
11.13	0.973
13.33	0.975
14.39	0.981
15.00	0.981
15.72	0.977
16.27	0.982
17.32	0.964
18.25	0.973
19.47	0.978
20.45	0.969
21.91	0.969
22.29	0.974
22.99	0.987
25.00	0.987
CURVE 3	
T = 673.	
1.88	0.653
2.23	0.672
2.61	0.698

λ	ε
CURVE 3(CONT.)	
2.80	0.726
2.93	0.761
3.04	0.786
3.17	0.786
3.44	0.735
3.80	0.690
3.99	0.690
4.31	0.717
4.47	0.744
4.63	0.779
4.86	0.856
5.02	0.886
5.17	0.904
5.34	0.922
5.75	0.923
6.01	0.950
6.35	0.970
7.27	0.967
7.80	0.968
8.97	0.971
9.10	0.968
9.56	0.966
10.28	0.966
10.64	0.981
10.92	0.988
12.00	0.997
12.83	0.997
13.78	0.994
15.40	0.994
18.39	0.989
19.09	0.975
20.32	0.975
21.18	0.959
21.90	0.969
22.41	0.961
22.69	0.967
23.24	0.967
23.81	0.979
24.48	0.981
25.11	0.989

λ	ε
CURVE 4	
T = 473.	
2.73	0.670
2.90	0.744
2.96	0.813
3.18	0.840
3.44	0.819
3.62	0.765
3.75	0.740
4.08	0.733
4.67	0.757
4.87	0.816
5.03	0.878
5.17	0.902
5.80	0.910
6.34	0.931
6.66	0.931
6.89	0.935
7.09	0.931
7.96	0.942
8.21	0.956
8.73	0.969
9.25	0.949
9.62	0.937
10.21	0.937
10.79	0.954
11.23	0.960
11.87	0.960
12.53	0.973
13.21	0.973
14.11	0.981
14.96	0.984
15.29	0.977
15.99	0.977
17.08	0.970
17.58	0.950
18.16	0.947
18.70	0.968
19.22	0.968
19.78	0.954
21.38	0.962

λ	ε
CURVE 4(CONT.)	
22.79	0.962
23.27	0.973
23.67	0.988
24.39	0.988
24.74	0.982
25.00	0.987
CURVE 5	
T = 673.	
1.91	0.679
2.20	0.714
2.41	0.737
2.59	0.739
2.77	0.754
2.94	0.754
3.12	0.742
3.23	0.722
3.33	0.686
3.51	0.650
3.75	0.629
3.88	0.618
4.19	0.607
4.49	0.628
4.94	0.671
5.23	0.703
5.69	0.708
5.88	0.736
6.02	0.769
6.19	0.778
6.39	0.764
6.57	0.793
6.74	0.834
6.90	0.841
7.11	0.829
7.32	0.859
7.52	0.922
7.68	0.952
7.84	0.969
8.10	0.979

λ	ε
CURVE 5(CONT.)	
8.56	0.979
8.74	0.984
9.037	0.983
9.56	0.968
9.80	0.956
10.22	0.956
10.80	0.976
11.65	0.982
12.16	0.988
12.82	0.998
13.78	0.994
15.40	0.994
18.01	0.989
18.42	0.993
19.09	0.990
19.99	0.990
20.71	0.975
22.32	0.975
22.86	0.969
23.44	0.965
23.79	0.967
24.48	0.962
25.15	0.962
CURVE 6	
T = 473.	
2.91	0.668
3.06	0.775
3.13	0.791
3.25	0.807
3.46	0.784
3.70	0.724
3.90	0.684
4.13	0.641
4.38	0.620
4.64	0.639
4.80	0.675
5.18	0.711
5.80	0.752

TABLE 19-3. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

λ	ϵ
CURVE	6 (CONT.)
6.04	0.780
6.09	0.818
6.33	0.835
6.57	0.812
6.81	0.838
6.88	0.875
7.14	0.865
7.50	0.879
7.66	0.943
7.83	0.976
8.07	0.994
8.59	0.994
8.88	0.985
9.09	0.986
9.35	0.968
9.79	0.939
10.29	0.939
10.79	0.954
11.15	0.966
12.41	0.972
13.92	0.972
14.60	0.959
15.22	0.949
15.86	0.949
17.09	0.954
18.09	0.959
18.67	0.957
19.79	0.951
21.02	0.959
23.19	0.959
23.60	0.967
23.98	0.978
24.91	0.978

b. Normal Spectral Reflectance (Wavelength Dependence)

There are 21 sets of experimental data available for the wavelength dependence of the normal spectral reflectance of silicone resin coating as listed in Table 19-6 and shown in Figure 19-4. Specimen characterization and measurement information for the data are given in Table 19-5. There were 10 different kinds of silicone used for measurements. The normal spectral reflectance values for silicone black paint (Pyrolac 7G 800) were the lowest. RTV-602 silicone on aluminum substrate has the highest reflectance values. Only Wilburn and Renius [T47062] and Wetmore [T40420] measured the normal spectral reflectance in the wavelength region above 2.6 μm. Because the range of reflectance for silicone is so wide, only provisional values are reported here which are listed in Table 19-4 and shown in Figure 19-3. The provisional values are for a 0.43 mm thick Dow Corning 6510 silicone on aluminum substrate at 400 K. The estimated uncertainty is within $\pm 30\%$.

TABLE 19-4. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
DC 6510	
T = 403	
1.75	0.52
2.00	0.50
2.10	0.59
2.15	0.21
2.22	0.17
2.40	0.18
2.50	0.21
2.56	0.21
2.70	0.07
2.80	0.22
3.00	0.24
3.10	0.04
3.30	0.03
3.60	0.04
3.80	0.39
3.84	0.42
4.00	0.29
4.05	0.44
4.15	0.47
4.25	0.44
4.50	0.18
4.80	0.07
5.00	0.05
5.50	0.05
7.00	0.09
7.50	0.10
8.00	0.13
8.50	0.16
9.00	0.19
9.30	0.23
10.00	0.22
10.50	0.21
11.00	0.21
11.50	0.21
12.00	0.21
12.50	0.22
13.00	0.22
13.50	0.23
14.00	0.23

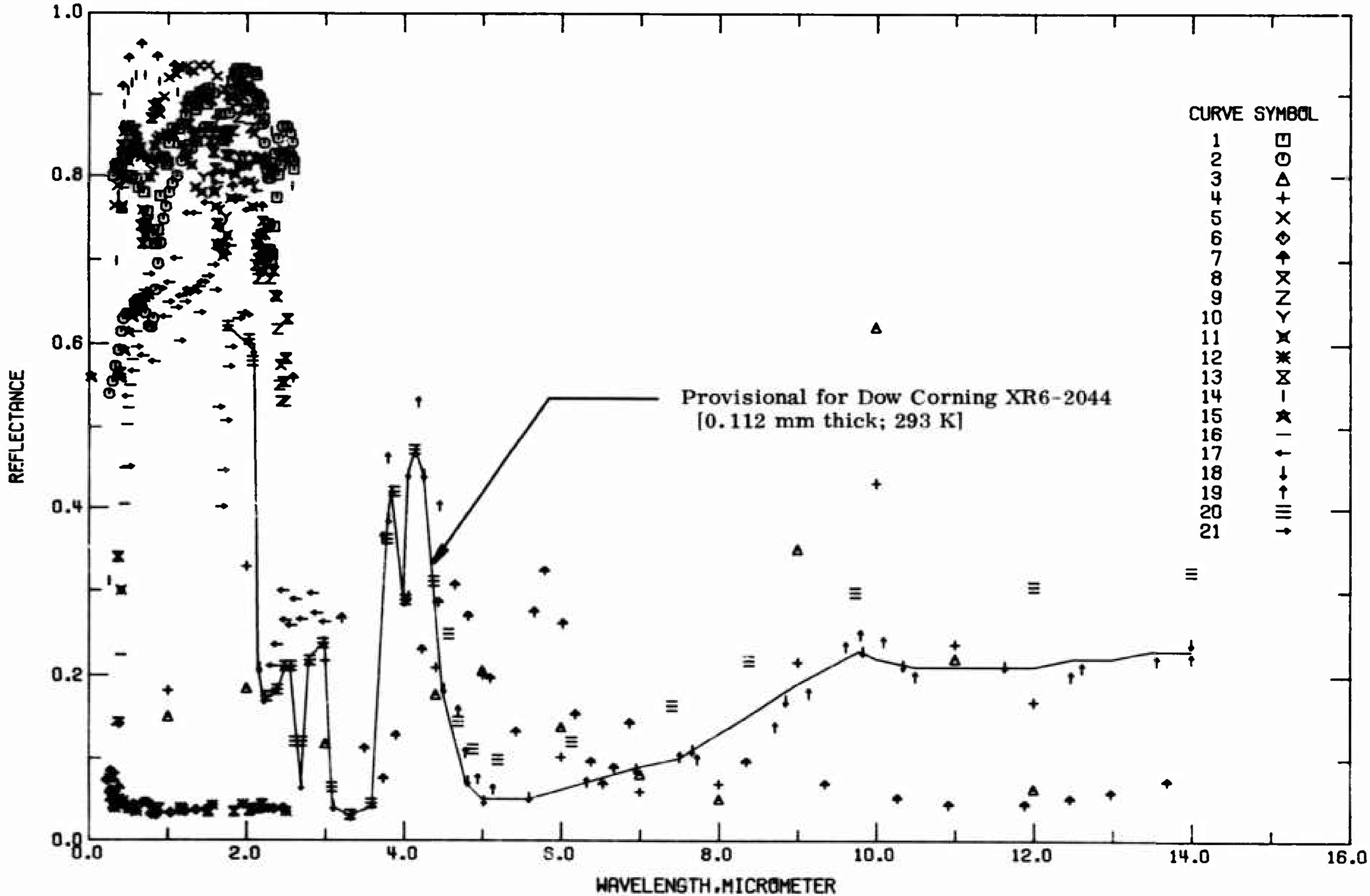


FIGURE 19-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF SILICONE RESIN COATING (WAVELENGTH DEPENDENCE).

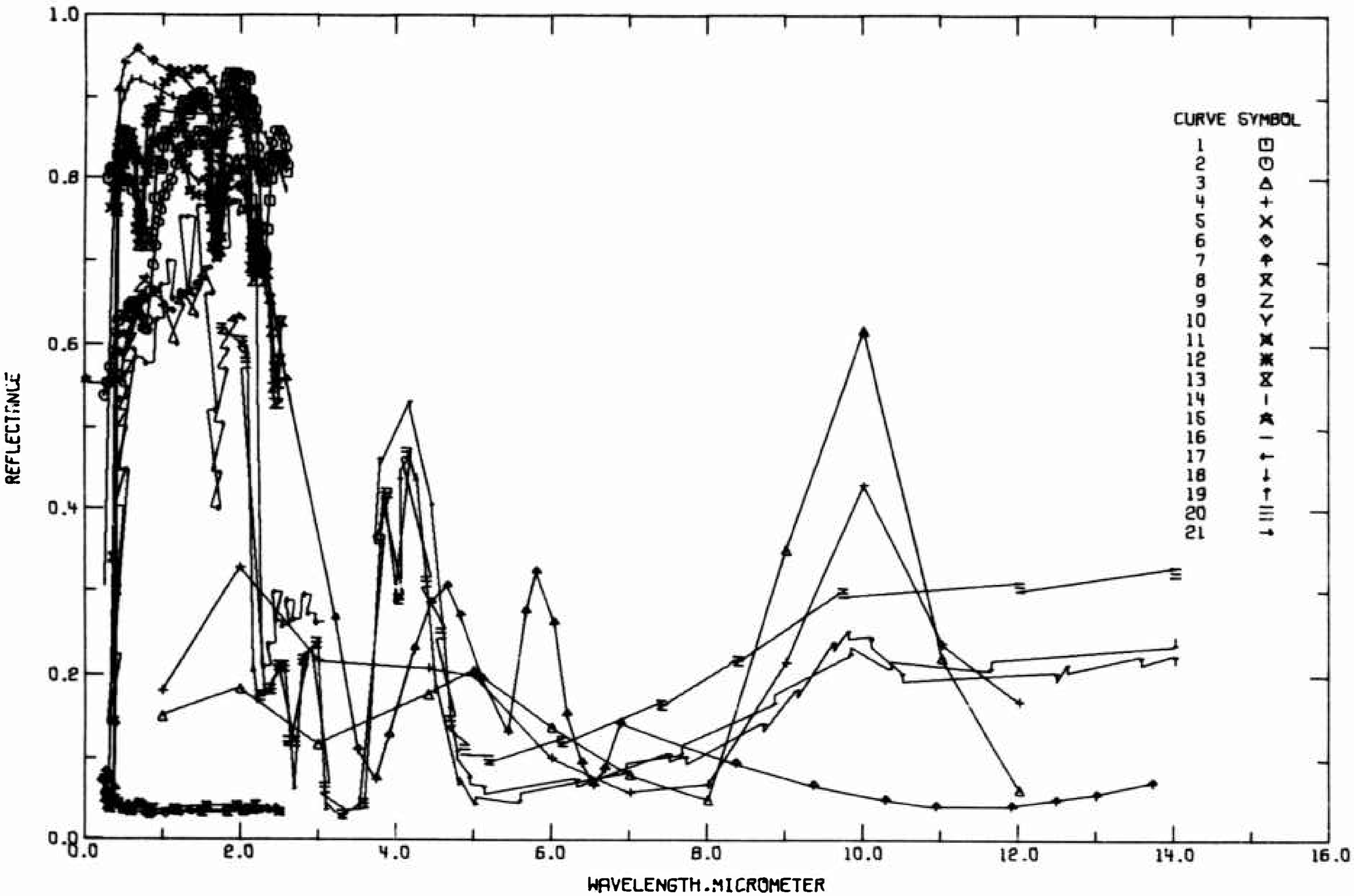


FIGURE 19-4. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICONE RESIN (WAVELENGTH DEPENDENCE).

TABLE 19-5. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF SILICONE RESIN COATING (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T41945	Caldwell, C.R. and Nelsen, P.A.	1969	0.25-2.6	~293	RTV-602	3.8 mil RTV-602 silicone over aluminum foil; data were extracted from figure; $\theta \sim 0°$.
2	T41945	Caldwell, C.R. and Nelsen, P.A.	1969	0.25-2.6	~293	RTV-602	Similar to the above specimen except 2.6 mil.
3	T47062	Wilburn, D.K. and Renius, O.	1955	1-12	~293	Silicone coated on cotton fabric	Silicone coated on cotton fabric; magnesium oxide was chosen as a standard for diffuse reflector; data were extracted from figure; $\theta \sim 0°$.
4	T47062	Wilburn, D.K. and Renius, O.	1955	1-12	~293	Silicone coated on cotton fabric	Similar to the above specimen.
5	T41421	Griffin, R.N. and Linder, B.	1969	0.3-2.3	~293	Silicone PJ 113 on Aluminum	General Electric experimental silicone resin 391-15-170 (PJ 113) was on aluminum substrate; data were extracted from figure; $\theta \sim 0°$.
6	T35934	Faugeras, J.F.	1965	0.3-2.6	~293	Pyrolac 7G800	Silicone black paint; a DK 2A spectrometer was used to measure the reflectance; $\theta \sim 0°$.
7	T53491	Marshall, K.N. and Brench, R.A.	1968	0.3-25	295	Silicone coating	White silicone coating on optical solar reflector; the spectral reflectance data were obtained using a Gier-Dunkle integrating sphere and a Gier Dunkle heated cavity directional reflectometer; data were extracted from figure; $\theta \sim 0°$.
8	T34045	Porter, J. and Butler, E.A.W.	1965	0.3-2.6	~293	White Silicone Paint F663-2020-1/001/35	Air dried on MKI integrating sphere; a Beckman DK 2A spectrometer was used; data were extracted from figure; $\theta \sim 0°$, $\omega' = 2\pi$.
9	T34045	Porter, J. and Butler, E.A.W.	1965	0.3-2.6	~293	White Silicone Paint F663-2020-1/001/35	Similar to the above specimen except cured at 250 C.
10	T34045	Porter, J. and Butler, E.A.W.	1965	0.3-2.6	~293	White Silicone Paint F663-2020-1/001/35	Similar to the above specimen except air dried on MKII sphere.
11	T34045	Porter, J. and Butler, E.A.W.	1965	0.3-2.6	~293	White Silicone Paint F663-2020-1/001/35	Similar to the above specimen except cured at 250 C.
12	T34045	Porter, J. and Butler, E.A.W.	1965	0.3-2.6	~293	Gloss Black Silicone Paint F663-2021-1/001/35	Similar to the above specimen except air dried on MKI sphere.
13	T34045	Porter, J. and Butler, E.A.W.	1965	0.3-2.6	~293	Gloss Black Silicone Paint F663-2021-1/001/35	Similar to the above specimen except air dried on MKII sphere.
14	T41934	Slemp, W.S. and Hankinson, T.W.E.	1969	0.3-2.6	~293	H-10	Calcined (Mono 90) clay-methyl silicone (RTV-602) specimen was obtained from Hughes Aircraft Co.; data were extracted from figure; $\theta \sim 0°$.
15	T29599	Carroll, W.F.	1962	0.021-0.751	298		DC808 silicone 3 parts by wt. TBT 2 parts by wt.; polished aluminum substrate; data were extracted from figure; $\theta \sim 0°$, $\omega' = 2\pi$.
16	T29599	Carroll, W.F.	1962	0.372-0.751	298		The above specimen except it was exposed to UV at about 10 runs for 22.75 hr; data were extracted from smooth curve.
17	T40420	Wetmore, R.A.	1963	0.49-3.00	300	Sample 29R	Dow Corning 6510 silicone (0.432 mm thick); aluminum substrate; data were extracted from smooth curve; $\theta = 5°$, $\omega' = 2\pi$.
18	T40420	Wetmore, R.A.	1963	1.76-14.0	389	Sample 31Ra	Similar to the above specimen.
19	T40420	Wetmore, R.A.	1963	3.72-14.0	422	Sample 30Ra	Similar to the above specimen.
20	T40420	Wetmore, R.A.	1963	1.76-14.0	450	Sample 31Rb	Similar to the above specimen.

TABLE 19-5. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF SILICONE RESIN COATING (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
21	T77381	Turner, H.C. and Keller, E.E.	1959	0.25-2.0	~293	X5G-138	Silicone/"5" glass; a Beckman DK-2 spectroreflectometer was used in measurements; data were extracted from smooth curve.

TABLE 19-5. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ
CURVE 1	
T = 293.	
0.313	0.798
0.344	0.809
0.368	0.812
0.406	0.812
0.434	0.826
0.540	0.798
0.608	0.794
0.626	0.784
0.693	0.778
0.744	0.755
0.812	0.727
0.835	0.717
0.856	0.717
0.880	0.733
0.907	0.774
0.930	0.820
0.949	0.820
0.983	0.811
0.999	0.815
1.016	0.838
1.032	0.847
1.057	0.856
1.142	0.855
1.183	0.861
1.227	0.871
1.266	0.889
1.295	0.895
1.347	0.884
1.350	0.878
1.369	0.884
1.407	0.900
1.432	0.901
1.462	0.894
1.489	0.885
1.504	0.897
1.515	0.906
1.580	0.899
1.666	0.873
1.728	0.848
CURVE 1 (CONT.)	
1.748	0.852
1.794	0.904
1.817	0.915
1.843	0.925
1.875	0.930
1.966	0.930
2.005	0.926
2.105	0.926
2.122	0.922
2.135	0.897
2.165	0.894
2.201	0.885
2.219	0.867
2.244	0.813
2.282	0.740
2.298	0.710
2.319	0.698
2.332	0.705
2.356	0.737
2.385	0.772
2.404	0.799
2.428	0.811
2.456	0.823
2.484	0.827
2.539	0.827
2.569	0.821
2.600	0.806
CURVE 2	
T = 293.	
0.255	0.539
0.296	0.554
0.335	0.572
0.376	0.591
0.411	0.613
0.434	0.628
0.479	0.634
0.560	0.635
0.581	0.647
CURVE 2 (CONT.)	
0.620	0.651
0.663	0.646
0.714	0.635
0.760	0.619
0.792	0.618
0.812	0.629
0.845	0.663
0.879	0.694
0.910	0.718
0.950	0.746
0.978	0.761
1.020	0.778
1.062	0.789
1.117	0.798
1.174	0.816
1.218	0.823
1.297	0.831
1.357	0.840
1.402	0.850
1.464	0.857
1.550	0.857
1.626	0.851
1.679	0.841
1.702	0.841
1.730	0.853
1.781	0.874
1.836	0.889
1.900	0.903
1.960	0.908
2.028	0.908
2.085	0.900
2.135	0.889
2.166	0.877
2.199	0.861
2.225	0.838
2.240	0.818
2.254	0.805
2.275	0.795
2.303	0.795
2.331	0.807
CURVE 2 (CONT.)	
2.362	0.825
2.402	0.843
2.455	0.858
2.520	0.858
2.555	0.850
2.583	0.839
2.600	0.817
CURVE 3	
T = 293.	
1.00	0.151
2.00	0.184
3.00	0.118
4.41	0.177
5.00	0.206
6.00	0.139
7.00	0.081
8.00	0.050
9.00	0.350
10.00	0.619
11.00	0.221
12.00	0.063
CURVE 4	
T = 293.	
1.00	0.181
2.00	0.328
3.00	0.217
4.41	0.209
5.00	0.200
6.00	0.102
7.00	0.059
8.00	0.069
9.00	0.216
10.00	0.430
11.00	0.238
12.00	0.169
CURVE 5	
T = 293.	
0.333	0.762
0.364	0.786
0.391	0.798
0.418	0.809
0.444	0.820
0.477	0.827
0.535	0.838
0.607	0.838
0.663	0.821
0.750	0.821
0.787	0.816
0.817	0.804
0.862	0.842
0.904	0.873
0.956	0.895
1.020	0.919
1.109	0.923
1.156	0.933
1.240	0.933
1.325	0.927
1.397	0.934
1.514	0.934
1.624	0.921
1.726	0.904
1.769	0.895
1.811	0.895
1.887	0.916
1.956	0.916
1.998	0.904
2.075	0.876
2.180	0.821
CURVE 6	
T = 293.	
0.23	0.073
0.28	0.0604
0.31	0.0529
0.35	0.0456
CURVE 6 (CONT.)	
0.40	0.0432
0.44	0.0423
0.57	0.0423
0.69	0.0451
0.74	0.0451
0.77	0.0424
0.79	0.0311
0.85	0.0307
1.03	0.0323
1.22	0.0344
1.36	0.0357
1.50	0.0364
2.09	0.0364
2.19	0.0371
2.35	0.0377
2.47	0.0385
CURVE 7	
T = 295.	
0.27	0.084
0.38	0.063
0.38	0.142
0.43	0.908
0.51	0.943
0.67	0.960
0.87	0.945
1.08	0.934
1.28	0.924
1.43	0.904
1.55	0.854
1.62	0.868
1.64	0.737
1.69	0.802
1.74	0.705
1.76	0.839
1.82	0.785
1.96	0.769
2.20	0.761
2.59	0.559

TABLE 19-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
CURVE	7 (CONT.)	CURVE	8 (CONT.)	CURVE	8 (CONT.)	CURVE	9 (CONT.)	CURVE	10 (CONT.)	CURVE	11 (CONT.)
3.21	0.267	0.396	0.564	2.467	0.554	2.151	0.676	1.623	0.780	1.616	0.761
3.50	0.112	0.413	0.759	2.503	0.582	2.186	0.688	1.652	0.757	1.628	0.716
3.74	0.075	0.417	0.835	2.524	0.628	2.186	0.706	1.670	0.736	1.700	0.703
3.90	0.128	0.446	0.851			2.233	0.706	1.697	0.717	1.755	0.727
4.23	0.231	0.477	0.858	CURVE 9		2.302	0.676	1.744	0.748	1.799	0.771
4.44	0.286	0.504	0.858	T = 293.		2.364	0.656	1.804	0.799	1.854	0.800
4.65	0.306	0.539	0.854			2.395	0.616	1.863	0.813	1.912	0.810
4.82	0.270	0.629	0.827	0.268	0.052	2.422	0.550	1.909	0.822	1.985	0.810
5.10	0.196	0.666	0.738	0.312	0.077	2.446	0.539	1.978	0.822	2.041	0.791
5.43	0.133	0.688	0.717	0.368	0.339	2.491	0.530	2.047	0.810	2.077	0.761
5.66	0.275	0.722	0.740	0.396	0.564	2.491	0.554	2.089	0.787	2.131	0.716
5.79	0.323	0.796	0.868	0.413	0.759	2.506	0.582	2.211	0.685	2.211	0.685
6.02	0.262	0.823	0.883	0.442	0.789	2.524	0.628				
6.18	0.154	0.882	0.886	0.466	0.818			CURVE 11		CURVE 12	
6.38	0.096	1.212	0.881	0.494	0.835	CURVE 10		T = 293.		T = 293.	
6.53	0.069	1.265	0.861	0.504	0.858	T = 293.					
6.57	0.089	1.314	0.846	0.589	0.854			0.325	0.038	0.263	0.075
6.87	0.144	1.369	0.840	0.629	0.827	0.325	0.038	0.372	0.049	0.324	0.058
8.35	0.096	1.540	0.840	0.666	0.738	0.372	0.049	0.405	0.299	0.425	0.047
9.35	0.069	1.583	0.826	0.688	0.717	0.405	0.299	0.422	0.762	0.513	0.039
10.27	0.051	1.607	0.807	0.722	0.740	0.422	0.762	0.461	0.793	0.599	0.034
10.92	0.043	1.633	0.740	0.796	0.868	0.422	0.799	0.508	0.815	0.835	0.034
11.89	0.043	1.658	0.715	0.823	0.883	0.457	0.824	0.550	0.826	1.154	0.039
12.46	0.050	1.739	0.823	0.882	0.886	0.513	0.839	0.595	0.843	1.563	0.042
12.98	0.057	1.778	0.853	1.212	0.881	0.595	0.843	0.647	0.832	1.954	0.043
13.70	0.072	1.877	0.887	1.265	0.861	0.647	0.832	0.684	0.757	2.226	0.038
14.49	0.118	1.959	0.694	1.314	0.846	0.684	0.757	0.718	0.726	2.500	0.034
14.94	0.136	2.031	0.879	1.369	0.840	0.718	0.726	0.745	0.742		
15.46	0.151	2.092	0.849	1.540	0.840	0.745	0.742	0.768	0.796	CURVE 13	
16.36	0.151	2.126	0.817	1.583	0.826	0.768	0.796	0.794	0.818	T = 293.	
17.02	0.165	2.142	0.723	1.607	0.807	0.794	0.818	0.828	0.834		
17.98	0.179	2.157	0.699	1.633	0.740	0.828	0.834	0.896	0.846	0.298	0.042
18.90	0.202	2.189	0.710	1.658	0.715	0.896	0.846	0.985	0.849	0.497	0.038
		2.189	0.727	1.777	0.822	0.985	0.849	1.065	0.849	0.884	0.038
CURVE 8		2.211	0.743	1.829	0.853	1.065	0.849	1.170	0.836	1.183	0.036
T = 293.		2.234	0.728	1.894	0.869	1.170	0.836	1.243	0.824	1.510	0.034
		2.250	0.701	1.955	0.879	1.243	0.824	1.299	0.811	1.841	0.034
0.268	0.052	2.348	0.685	2.048	0.856	1.299	0.811	1.351	0.784	2.036	0.035
0.312	0.077	2.389	0.654	2.095	0.819	1.455	0.796	1.426	0.778	2.109	0.038
0.368	0.339	2.441	0.574	2.120	0.692	1.567	0.796	1.587	0.778	2.195	0.043

TABLE 19-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

CURVE 14
T = 293.

λ	ρ
0.253	0.310
0.351	0.697
0.374	0.775
0.385	0.822
0.405	0.857
0.443	0.885
0.495	0.902
0.542	0.913
0.593	0.922
0.709	0.922
0.889	0.914
1.123	0.901
1.381	0.895
1.743	0.889
1.940	0.883
2.100	0.873
2.209	0.862
2.312	0.853
2.406	0.834
2.491	0.815
2.580	0.786

CURVE 15
T = 298.

λ	ρ
0.021	0.560
0.370	0.560
0.399	0.560
0.449	0.591
0.499	0.613
0.550	0.631
0.601	0.644
0.649	0.648
0.701	0.655
0.751	0.658

CURVE 16
T = 298.

λ	ρ
0.372	0.149
0.399	0.224
0.449	0.403
0.466	0.447
0.487	0.502
0.500	0.522
0.518	0.550
0.549	0.580
0.600	0.613
0.649	0.637
0.702	0.654
0.751	0.658

CURVE 17
T = 300.

λ	ρ
0.49	0.536
0.57	0.567
0.69	0.585
0.83	0.578
0.97	0.631
1.02	0.672
1.11	0.700
1.17	0.656
1.26	0.664
1.27	0.753
1.36	0.753
1.40	0.667
1.45	0.673
1.50	0.766
1.63	0.790
1.80	0.715
1.90	0.769
1.94	0.773
2.02	0.757
2.13	0.780
2.33	0.211
2.39	0.237
2.47	0.299

CURVE 17 (CONT.)

λ	ρ
2.50	0.265
2.57	0.259
2.63	0.289
2.71	0.266
2.85	0.296
2.90	0.273
3.00	0.263

CURVE 18
T = 389.

λ	ρ
1.76	0.620
2.03	0.604
2.09	0.592
2.16	0.209
2.22	0.172
2.38	0.183
2.48	0.211
2.56	0.211
2.69	0.067
2.79	0.217
2.98	0.240
3.10	0.041
3.32	0.030
3.60	0.044
3.80	0.386
3.84	0.420
4.01	0.288
4.06	0.293
4.05	0.441
4.15	0.468
4.25	0.440
4.51	0.184
4.81	0.073
5.02	0.048
5.59	0.052
6.95	0.088
7.66	0.111
8.85	0.171
9.33	0.230

CURVE 18 (CONT.)

λ	ρ
10.34	0.213
11.63	0.212
14.00	0.240

CURVE 19
T = 422.

λ	ρ
3.72	0.363
3.79	0.460
4.18	0.529
4.45	0.402
4.69	0.158
4.78	0.107
4.94	0.075
5.13	0.062
6.32	0.071
7.50	0.102
7.72	0.099
8.71	0.139
9.14	0.179
9.61	0.235
9.80	0.249
10.09	0.241
10.49	0.199
12.47	0.199
12.61	0.209
13.56	0.218
14.00	0.220

CURVE 20
T = 450.

λ	ρ
1.76	0.620
2.03	0.604
2.07	0.579
2.25	0.175
2.39	0.183
2.49	0.211
2.56	0.211
2.61	0.121

CURVE 20 (CONT.)

λ	ρ
2.70	0.121
2.80	0.218
2.97	0.239
3.08	0.065
3.31	0.031
3.58	0.045
3.78	0.362
3.87	0.420
4.02	0.289
4.13	0.471
4.38	0.311
4.57	0.250
4.69	0.146
4.88	0.112
5.19	0.099
6.13	0.121
7.40	0.165
8.38	0.218
9.73	0.298
12.00	0.305
14.00	0.323

CURVE 21
T = 293.

λ	ρ
0.350	0.141
0.502	0.449
0.602	0.595
0.702	0.663
0.757	0.682
0.903	0.665
1.002	0.649
1.103	0.642
1.147	0.602
1.217	0.649
1.250	0.659
1.301	0.665
1.350	0.661
1.399	0.636
1.450	0.673

CURVE 21 (CONT.)

λ	ρ
1.506	0.680
1.575	0.693
1.601	0.663
1.641	0.523
1.678	0.401
1.701	0.445
1.739	0.507
1.775	0.572
1.798	0.595
1.898	0.629
1.951	0.636
2.000	0.633

c. Angular Spectral Reflectance (Wavelength Dependence)

There are seven sets of experimental data available for the wavelength dependence of the angular spectral reflectance of silicone resin coatings as listed in Table 19-9 and shown in Figure 19-6. Specimen characterization and measurement information for the data are given in Table 19-8. Only specular reflectance data were measured. All the specimens were coated over silver thin films and there is no information on the thickness of the silicone coating and silver thin film. As a consequence of these difficulties, only provisional values are reported here which are listed in Table 19-7 and shown in Figure 19-5 with the experimental data as background. The estimated uncertainty is about ± 30%.

TABLE 19-7. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
COATING $\theta' = \theta = 45°$ T = 293	
1.00	0.45
1.50	0.62
2.00	0.73
2.50	0.75
3.00	0.77
3.50	0.79
4.00	0.81
4.50	0.84
5.00	0.85
5.50	0.86
6.00	0.87
6.50	0.87
7.00	0.87
7.50	0.87
8.00	0.88
8.50	0.88
9.00	0.89
9.50	0.89
10.00	0.89
10.50	0.90
11.00	0.90
11.50	0.91
12.00	0.91
12.50	0.91
13.00	0.91
13.50	0.91
14.00	0.91
14.50	0.91
15.00	0.91

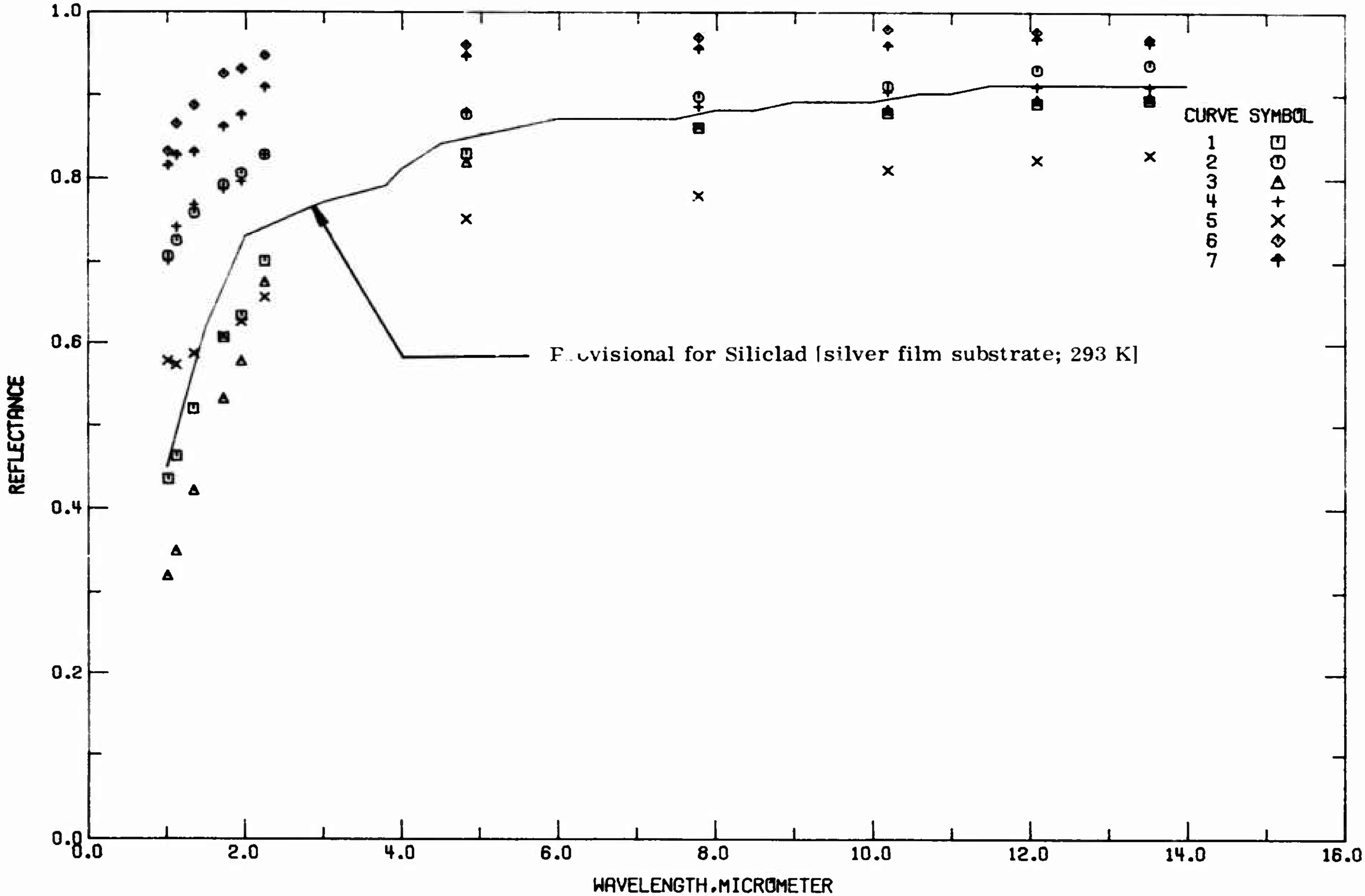


FIGURE 19-5. PROVISIONAL ANGULAR SPECTRAL REFLECTANCE OF SILICONE RESIN COATING (WAVELENGTH DEPENDENCE).

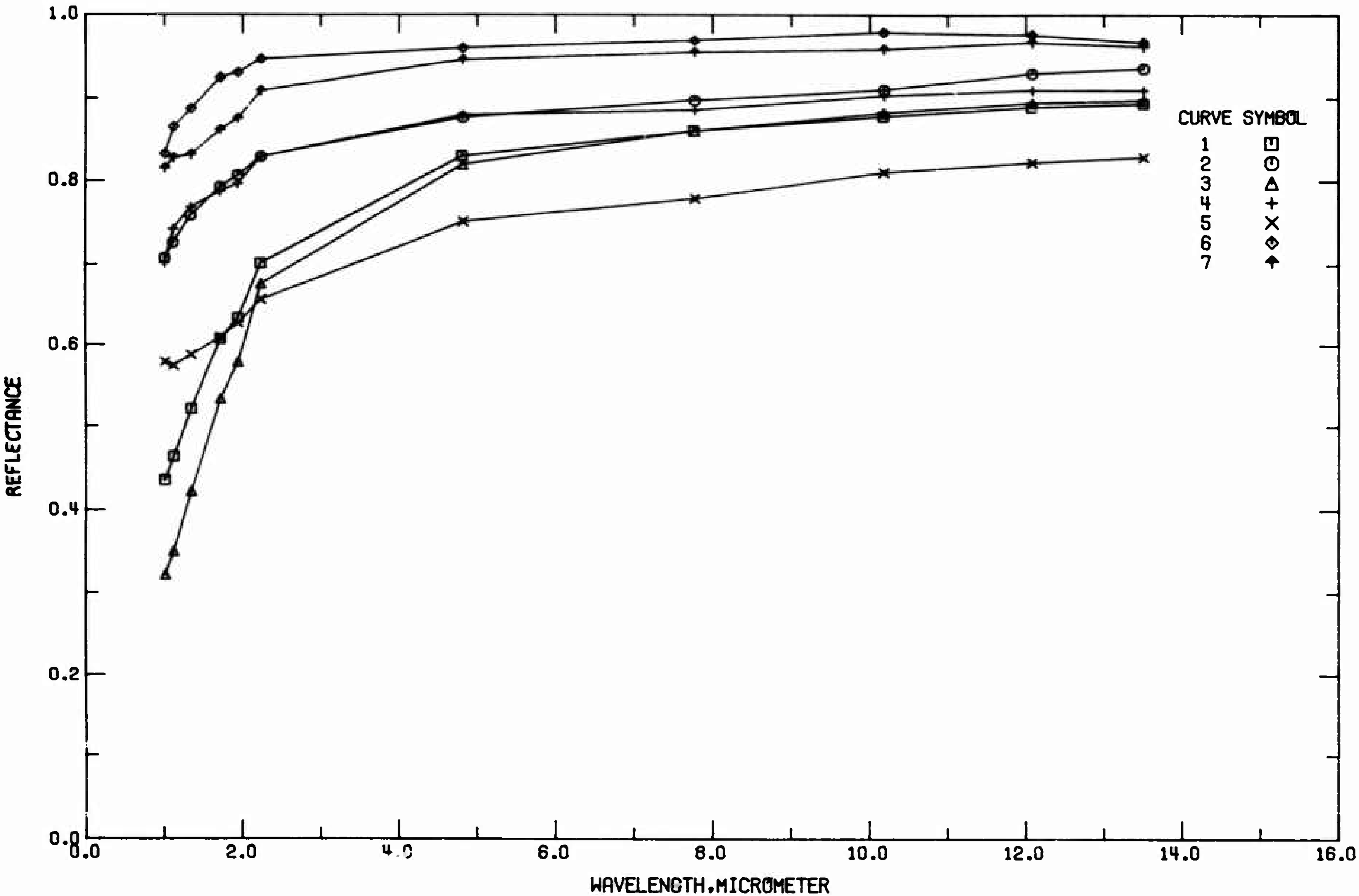


FIGURE 19-6. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF SILICONE RESIN (WAVELENGTH DEPENDENCE).

TABLE 19-8. MEASUREMENT INFORMATION ON THE ANGULAR SPECTRAL REFLECTANCE OF SILICONE RESIN COATING (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T33358	Belser, R.B., Carithers, M.D., Britt, F.L., Meaders, J.C., Elston, L.W., Koralek, A.S., Cooke, J.C., and Frahm, C.P.	1962	1-14.4	~293	Ag 87 CS	Siliclad; silicone resin over coating on a silver film which is deposited on silicone resin coated 316 stainless steel substrate; silver film was applied by Brashear method; specular reflectance; data were extracted from the table; θ=45°, θ'=45°.
2	T33358	Belser, R.B., et al.	1962	1-14.4	~293	Ag 88 CS	Similar to the above specimen.
3	T33386	Belser, R.B., et al.	1962	1-14.4	~293	Ag 89 CS	Similar to the above specimen.
4	T33358	Belser, R.B., et al.	1962	1-14.4	~293	Ag 90 CS	Similar to the above specimen except silver film was deposited on SY627-119 polyurethane (Febert Shorndorfer Co.), and 316 stainless steel substrates.
5	T33338	Belser, R.B., et al.	1962	1-14.4	~293	Ag 91 CS	Similar to the above specimen.
6	T33358	Belser, R.B., et al.	1962	1-14.4	~293	Ag 92 CS	Similar to the above specimen except silver film was deposited on Maraset 617-C epoxy resin (Marblett Co.), and 316 stainless steel substrate.
7	T33398	Belser, R.B., et al.	1962	1-14.4	~293	Ag 93 CS	Similar to the above specimen.

TABLE 19-9. EXPERIMENTAL ANGULAR SPECTRAL REFLECTANCE OF SILICONE RESIN (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1	
T = 293.	
1.009	0.435
1.120	0.463
1.345	0.519
1.720	0.606
1.945	0.633
2.240	0.700
4.824	0.828
7.780	0.859
10.198	0.877
12.099	0.888
13.530	0.892
14.375	0.889
CURVE 2	
T = 293.	
1.009	0.706
1.120	0.725
1.345	0.757
1.720	0.791
1.945	0.805
2.240	0.827
4.824	0.875
7.780	0.896
10.198	0.909
12.099	0.928
13.530	0.934
14.375	0.932
CURVE 3	
T = 293.	
1.009	0.320
1.120	0.349
1.345	0.422
1.720	0.531
1.945	0.577
2.240	0.675
4.824	0.818

λ	ρ
CURVE 3(CONT.)	
7.780	0.859
10.198	0.881
12.099	0.893
13.530	0.896
14.375	0.892
CURVE 4	
T = 293.	
1.009	0.700
1.120	0.741
1.345	0.767
1.720	0.786
1.945	0.795
2.240	0.827
4.824	0.878
7.780	0.884
10.198	0.902
12.099	0.908
13.530	0.908
14.375	0.917
CURVE 5	
T = 293.	
1.009	0.577
1.120	0.572
1.345	0.586
1.720	0.608
1.945	0.626
2.240	0.656
4.824	0.750
7.780	0.778
10.198	0.809
12.099	0.821
13.530	0.827
14.375	0.842

λ	ρ
CURVE 6	
T = 293.	
1.009	0.831
1.120	0.864
1.345	0.886
1.720	0.923
1.945	0.929
2.240	0.945
4.824	0.958
7.780	0.967
10.198	0.977
12.099	0.974
13.530	0.965
14.375	0.953
CURVE 7	
T = 293.	
1.009	0.814
1.120	0.826
1.345	0.830
1.720	0.860
1.945	0.874
2.240	0.907
4.824	0.944
7.780	0.953
10.198	0.957
12.099	0.965
13.530	0.960
14.375	0.962

d. Normal Spectral Transmittance (Wavelength Dependence)

There are 26 sets of experimental data available for the wavelength dependence of the normal spectral reflectance of silicone resin as listed in Table 19-9 and shown in Figure 19-6 (bulk materials) and Figure 19-7 (thin films). Specimen characterization and measurement information for the data are given in Table 19-8. There were 22 different kinds of silicone resins used for measurement; their transmittance values were quite different. Therefore, only provisional values are reported here which are listed in Table 19-7 and shown in Figure 19-5. The provisional values are for Dow Corning XR6-2044 silicone resin with thickness 0.112 mm at 293 K. The estimated uncertainty is about ±30%.

TABLE 19-12. PROVISIONAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
DC XR6-2044	
0.112 MM THICK	
T = 293	
0.30	0.34
0.40	0.86
0.50	0.88
0.70	0.89
1.00	0.90
1.25	0.90
1.35	0.89
1.40	0.87
1.45	0.88
1.50	0.59
1.60	0.39
1.62	0.88
1.64	0.71
1.66	0.58
1.68	0.40
1.70	0.35
1.71	0.33
1.74	0.66
1.76	0.63
1.78	0.70
1.80	0.77
1.83	0.80
1.85	0.84
1.90	0.85
2.00	0.86
2.15	0.86

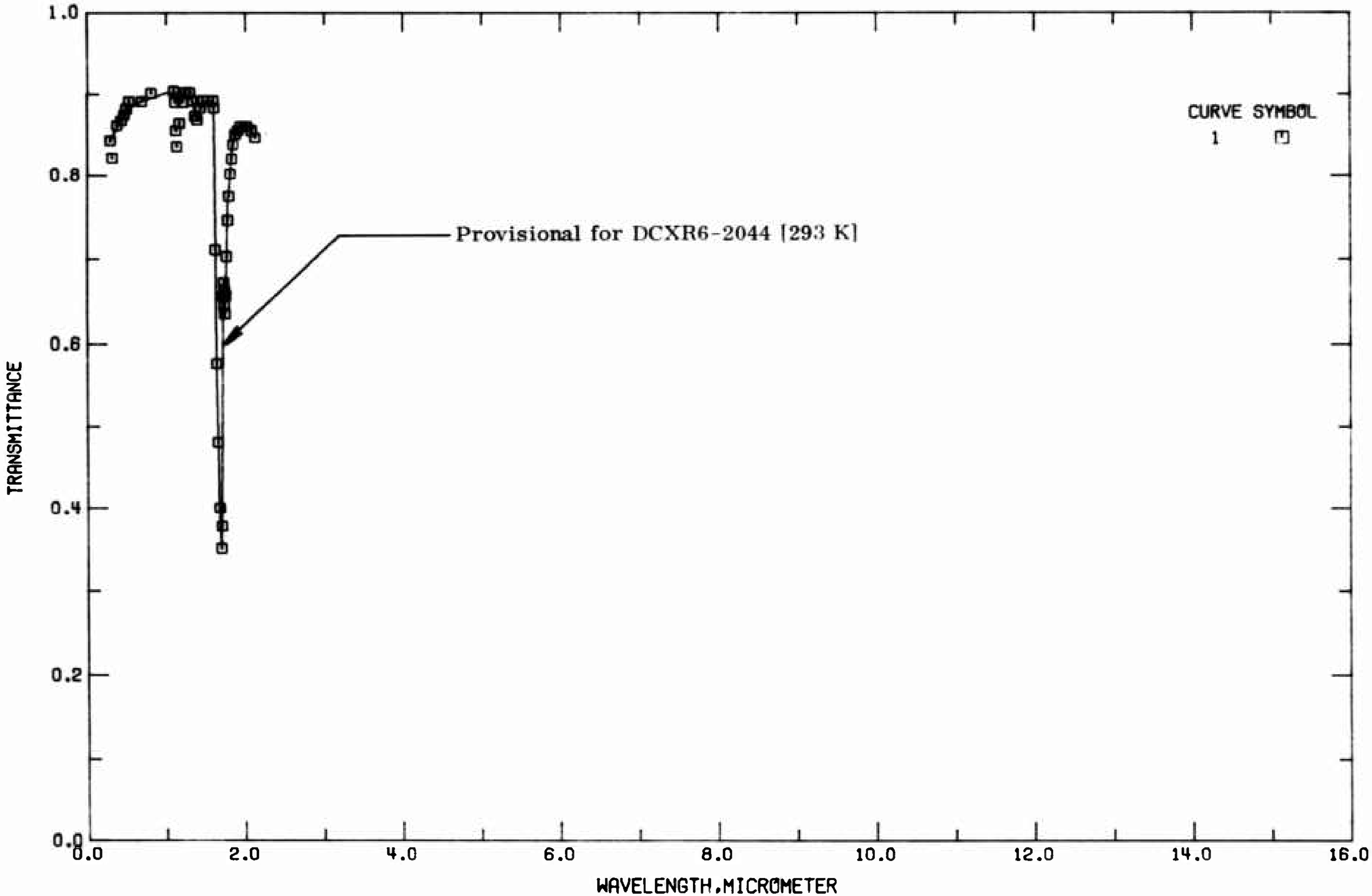


FIGURE 19-7. PROVISIONAL NORMAL SPECTRAL TRANSMITTACNE OF SILICONE RESIN (WAVELENGTH DEPENDENCE).

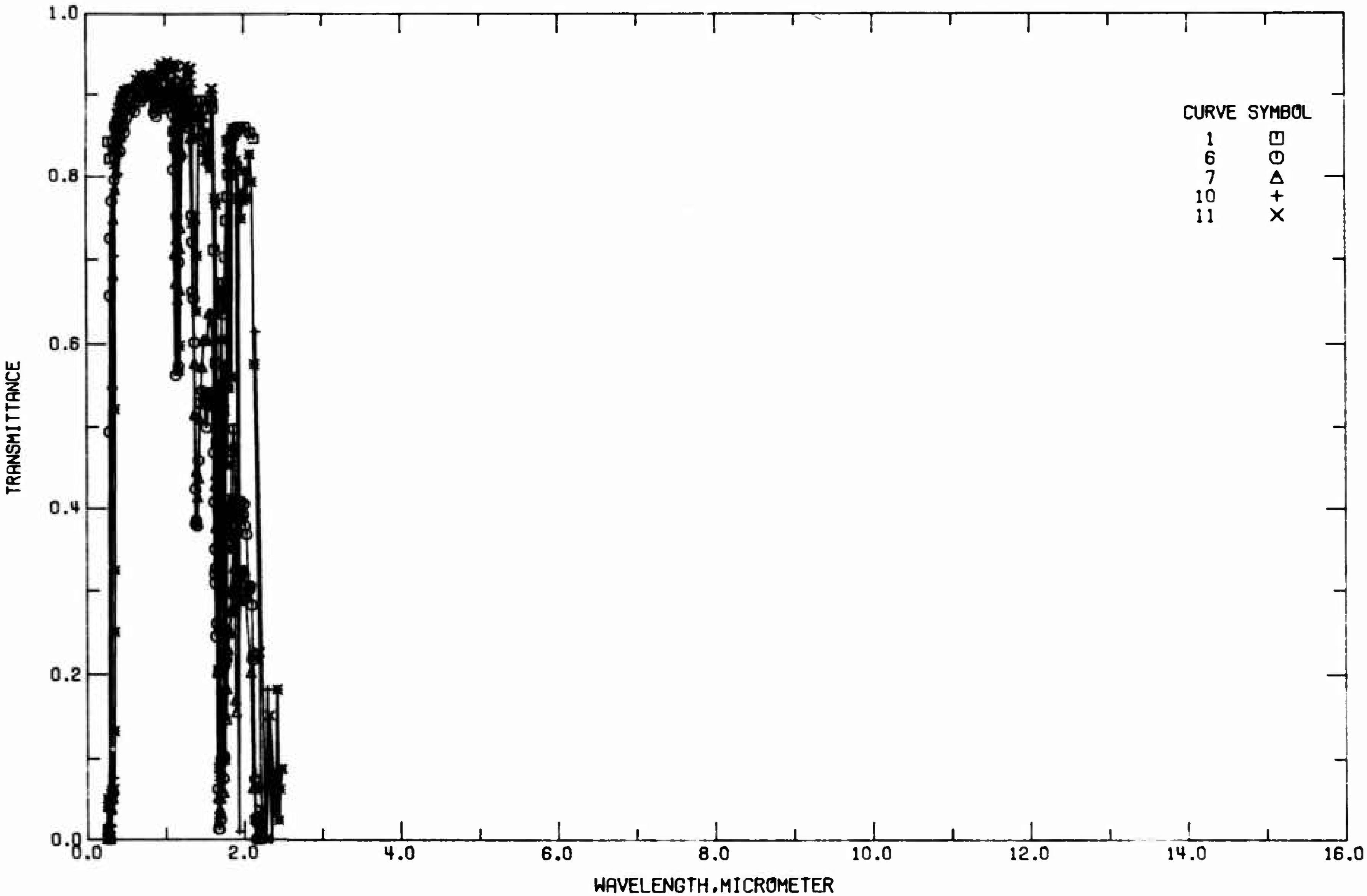


FIGURE 19-8. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICONE RESIN (WAVELENGTH DEPENDENCE).

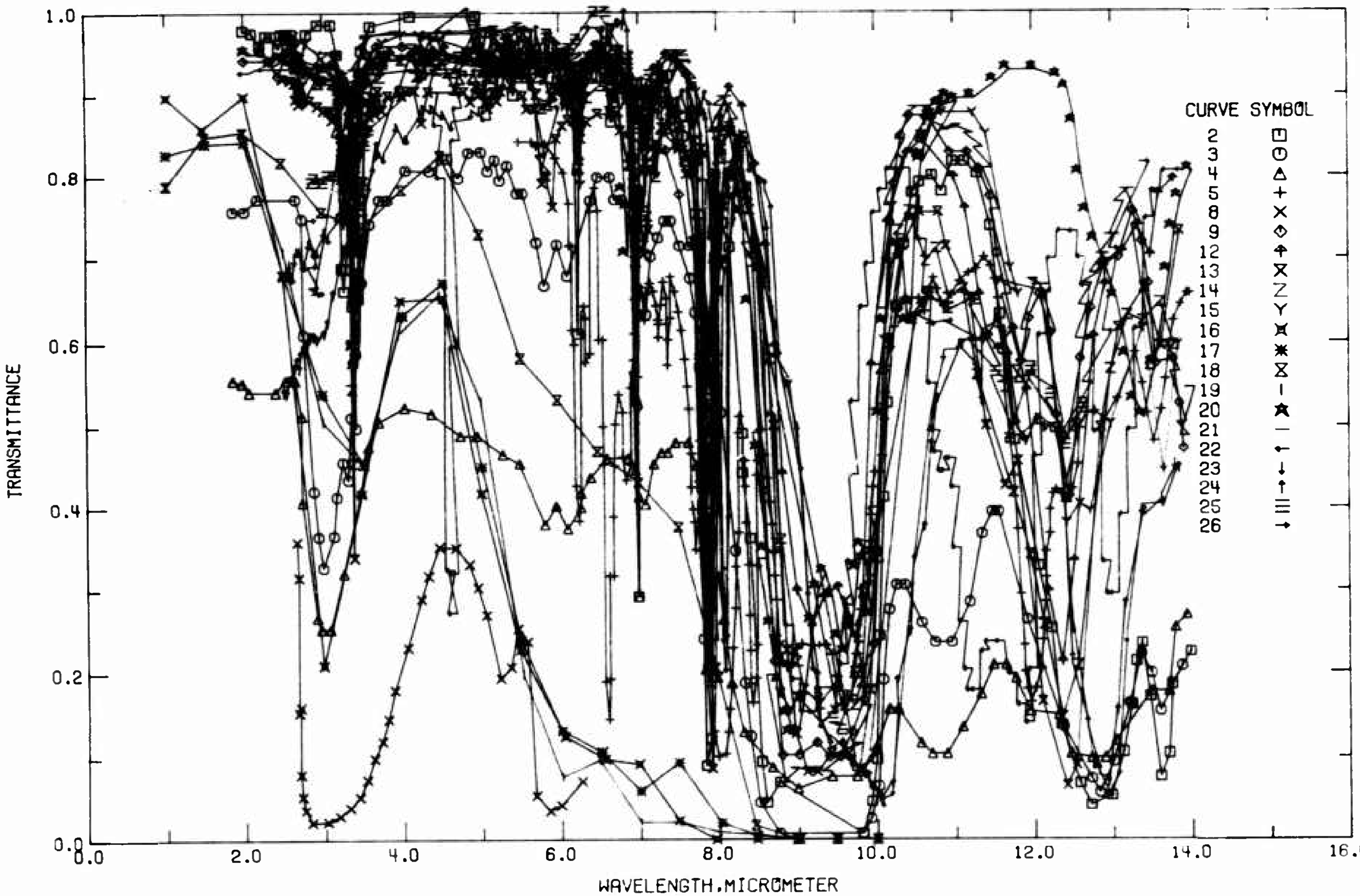


FIGURE 19-9. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICONE RESIN COATINGS (WAVELENGTH DEPENDENCE).

TABLE 19-11. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF SILICONE RESINS (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T19818	Wituchi, R.M. and Lewis, A.E.	1961	0.3-2.1	293	XR6-2044 Resin (Dow Corning)	0.046 in. thick with no substrate, curve not corrected for reflection losses; measurements on Dow Corning 805 and Dow Corning 4000 resins showed all to be very similar; $\theta \sim 0°$.
2	T24833	Cowling, J.E., Alexander, A.V., Noonan, F., Kagarise, R., and Stokes, S.	1960	2-15	293	Phenyl Silicone Resin Film	Film-forming polymers in a vacuum of approx. 10^{-6} mm pressure; $\theta \sim 0°$.
3	T24833	Cowling, J.E., et al.	1960	2-15	293	Phenyl Silicone Resin Film	Similar to the above specimen except film was exposed to mercury vapor lamp 80 hr (11.3 mW/cm^2 at 10 cm).
4	T24833	Cowling, J.E., et al.	1960	2-15	293	Phenyl Silicone Resin Film	Similar to the above specimen except film was exposed to mercury vapor lamp 250 hr.
5	T35546	Zerlaut, G.A.	1960	5.5-14	293	Dow Corning 808	No thickness or details given; $\theta \sim 0°$.
6	T40338	Acitelli, M.A., Gamby, W.L., and Nujokas, A.A.	1966	0.2-2.2	296	Glass Resin 100	6.67 mm thick disc approx. 50 mm in diameter; specimen was obtained from Owen-Illinois; Cary spectrophotometer was used for measurements; $\theta \sim 0°$.
7	T40338	Acitelli, M.A., et al.	1966	0.2-2.2	296	Glass Resin 100 "CR 39"	Similar to the above specimen except 6.75 mm thick.
8	T51317 T51318	Chuiko, A.A., Pavlik, G.E., Tertykh, V.A., Chuiko, E.A., Artenov, V.A., Neimark, I.E., and Tsipenyuk, E.V.	1966	2.7-5.5	295	Carboxyorganosilica	Powder specimen; $\theta \sim 0°$.
9	T51594	Story, J.G.	1961	2-15	296	Silicone	No thickness was given; $\theta \sim 0°$.
10	T61459	Williams, J.G. and Judd, J.H.	1971	0.23-2.5	293	Silicone 1	3.064 mm thick; 100 dimethyl silicone rubber RTV 615 part A and 10 RTV 615 part B; the specimen was cast, cured 2 hr at 71 C; $\theta \sim 0°$.
11	T61459	Williams, J.G. and Judd, J.H.	1971	0.23-2.5	293	Silicone 2	2.976 mm thick; 100 dimethyl silicone rubber Sylgard 184 part A and 10 Sylgard 184 part B; the specimen was cast, cured 2 hr at 71 C; $\theta \sim 0°$.
12	T76798	Lara, M.O.	1967	2.5-25	~293	Silastic 916 (Dow Corning Co.)	The specimen was condensed pyrolyzate on potassium bromide or sodium chloride; a Beckman IR-9 double beamed, prism-grating infrared spectrophotometer was used to obtain the spectra; data were extracted from figure; $\theta \sim 0°$.
13	T76798	Lara, M.O.	1967	2.5-25	~293	Silastic 6526 (Dow Corning Co.)	Similar to the above specimen.
14	T76798	Lara, M.O.	1967	2.5-25	~293	Silicone Rubber Heat Shrinkable (Dow Corning Co.)	Similar to the above specimen.
15	T76798	Lara, M.O.	1967	2.5-25	~293	5542 Silicone Finish Aluminum Silicone (Dutch Boy)	Similar to the above specimen.
16	T45212	Schmidt, R.N.	1967	1-10	~293	Dow Corning Silicone 991	0.014 in. thick (356 μ); not baked; data were extracted from figure; $\theta \sim 0°$.

TABLE 19-11. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL TRANSMITTANCE OF SILICONE RESINS (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
17	T45212	Schmidt, R.N.	1967	1-10	~293	Dow Corning Silicone 991	Similar to the above specimen except it was baked at 600 F.
18	T45212	Schmidt, R.N.	1967	1-10	~293	General Electric Silicone PT	0.003 in. thick specimen after 600 F bake; data were extracted from figure; $\theta \sim 0°$.
19	T45212	Schmidt, R.N.	1967	1-10	~293	General Electric Silicone 120	0.0175 in. thick specimen after 600 F bake; data were extracted from figure; $\theta \sim 0°$.
20	T76812	Kagarise, R.E. and Weinberger, L.A.	1954	2-15	~293	Silicone Resin 4746-26A	The specimen was obtained from Linde Air Products; it was dissolved in C_6H_6 and the resulting viscous solution was spread uniformly on rock salt or KBr plate; the solvent was removed by heating in vacuum or normal evaporation at room temperature; a Perkin-Elmer spectrophotometer was used in measurement; data were extracted from figure; $\theta \sim 0°$.
21	T76812	Kagarise, R.E. and Weinberger, L.A.	1954	2-15	~293	Silicone Resin 173-8-211	Similar to the above specimen except obtained from General Electric Co.
22	T76812	Kagarise, R.E. and Weinberger, L.A.	1954	2-15	~293	Dow Corning 1107	Similar to the above specimen except obtained from Dow Corning Co.
23	T68915	Jayme, G. and Traser, G.	1972	2.5-25	~293	Silicone Resin	The transmittance spectra was obtained by using FMIR technique (multiple reflection); data were extracted from figure; $\theta \sim 0°$.
24	T68915	Jayme, G. and Traser, G.	1972	2.5-25	~293	Silicone coated paper	Similar to the above specimen.
25	T77141	Tkachuk, B.V., Perova, L.V., and Kololyskin, V.M.	1971	3-12	~293	HMDS film	Hexamethyldisiloxane film about 0.5-2 μm thick was prepared in a silence discharge; $\theta \sim 0°$.
26	T77141	Tkachuk, B.V., et al.	1971	3-12	~293	HMDS film	Similar to the above specimen except it was irradiated by 400 Mrad dose γ-ray.

TABLE 19-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 1		CURVE 1 (CONT.)		CURVE 2 (CONT.)		CURVE 2 (CONT.)		CURVE 2 (CONT.)		CURVE 3 (CONT.)	
T = 293.		1.827	0.801	5.16	0.975	8.17	0.712	14.07	0.278	5.10	0.805
0.300	0.841	1.843	0.819	5.23	0.902	8.32	0.490	14.24	0.114	5.19	0.818
0.324	0.820	1.864	0.836	5.28	0.940	8.32	0.442	14.28	0.082	5.25	0.793
0.367	0.860	1.893	0.849	5.34	0.955	8.41	0.361	14.33	0.072	5.35	0.811
0.442	0.866	1.926	0.854	5.44	0.898	8.54	0.095	14.41	0.107	5.47	0.777
0.480	0.873	1.957	0.859	5.48	0.932	8.60	0.045	14.52	0.501	5.54	0.777
0.506	0.881	2.034	0.859	5.55	0.945	8.76	0.07	14.60	0.568	5.71	0.718
0.537	0.890	2.101	0.853	5.61	0.920	9.82	0.007	14.66	0.583	5.81	0.665
0.699	0.890	2.147	0.845	5.73	0.945	9.93	0.047	14.80	0.601	5.97	0.715
0.819	0.900			5.86	0.945	10.00	0.098	15.00	0.678	6.10	0.677
1.112	0.903	CURVE 2		6.01	0.916	10.04	0.243			6.40	0.768
1.126	0.889	T = 293.		6.09	0.937	10.11	0.412	CURVE 3		6.49	0.797
1.136	0.854			6.20	0.900	10.16	0.527	T = 293.		6.65	0.797
1.147	0.834	2.00	0.977	6.24	0.609	10.28	0.640			6.71	0.769
1.182	0.863	2.11	0.974	6.27	0.868	10.38	0.716	1.85	0.755	6.80	0.769
1.225	0.889	2.21	0.959	6.31	0.897	10.49	0.778	2.00	0.755	6.92	0.743
1.263	0.901	2.29	0.970	6.44	0.923	10.58	0.791	2.16	0.770	6.99	0.291
1.309	0.901	2.36	0.970	6.49	0.940	10.74	0.799	2.65	0.770	7.00	0.630
1.342	0.891	2.45	0.956	6.60	0.943	10.86	0.779	2.73	0.746	7.10	0.631
1.378	0.872	2.53	0.973	6.68	0.865	11.00	0.816	2.75	0.608	7.16	0.700
1.409	0.867	2.62	0.973	6.71	0.917	11.15	0.816	2.87	0.419	7.26	0.723
1.446	0.882	2.74	0.933	6.76	0.936	11.31	0.801	2.92	0.363	7.34	0.743
1.479	0.891	2.81	0.973	6.89	0.906	11.47	0.737	2.98	0.326	7.42	0.743
1.610	0.891	2.95	0.984	6.94	0.820	11.59	0.631	3.12	0.364	7.53	0.713
1.617	0.882	3.12	0.984	6.99	0.291	11.77	0.482	3.16	0.412	7.66	0.674
1.637	0.710	3.20	0.949	7.01	0.767	12.07	0.328	3.24	0.455	7.73	0.633
1.653	0.577	3.24	0.687	7.08	0.755	12.23	0.252	3.31	0.433	7.81	0.239
1.665	0.480	3.27	0.659	7.15	0.869	12.35	0.138	3.35	0.510	7.84	0.090
1.682	0.400	3.29	0.686	7.22	0.899	12.58	0.069	3.41	0.497	7.90	0.121
1.703	0.350	3.32	0.710	7.33	0.922	12.72	0.042	3.41	0.586	7.97	0.498
1.711	0.377	3.32	0.753	7.40	0.922	12.98	0.054	3.49	0.670	8.05	0.515
1.739	0.656	3.38	0.711	7.53	0.837	13.14	0.106	3.59	0.740	8.22	0.346
1.745	0.672	3.38	0.844	7.59	0.847	13.25	0.162	3.72	0.769	8.33	0.187
1.753	0.663	3.43	0.900	7.62	0.816	13.31	0.212	3.82	0.769	8.40	0.124
1.755	0.645	3.51	0.953	7.70	0.824	13.38	0.234	4.06	0.806	8.51	0.045
1.762	0.635	3.62	0.982	7.75	0.714	13.48	0.171	4.36	0.805	8.76	0.007
1.770	0.657	4.13	0.994	7.84	0.090	13.61	0.077	4.59	0.820	9.82	0.007
1.780	0.702	4.97	0.994	7.90	0.121	13.72	0.104	4.73	0.796	9.92	0.025
1.796	0.745	5.05	0.944	7.99	0.700	13.76	0.185	4.86	0.827	10.02	0.065
1.809	0.774	5.10	0.975	8.08	0.741	14.00	0.223	5.02	0.828	10.09	0.191

TABLE 19-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE	3(CONT.)	CURVE	4(CONT.)	CURVE	4(CONT.)	CURVE	5(CONT.)	CURVE	5(CONT.)	CURVE	5(CONT.)
10.17	0.275	2.90	0.265	9.74	0.077	6.12	0.765	7.00	0.635	7.99	0.101
10.26	0.305	2.95	0.251	9.99	0.112	6.12	0.714	7.04	0.663	8.08	0.104
10.37	0.305	3.07	0.251	10.16	0.157	6.16	0.714	7.06	0.652	8.11	0.129
10.58	0.259	3.24	0.319	10.27	0.157	6.16	0.614	7.08	0.625	8.13	0.157
10.75	0.235	3.47	0.419	10.56	0.116	6.19	0.597	7.10	0.655	8.16	0.183
10.96	0.235	3.57	0.474	10.70	0.104	6.20	0.426	7.15	0.668	8.18	0.228
11.19	0.284	3.70	0.505	10.89	0.104	6.24	0.383	7.19	0.658	8.21	0.277
11.35	0.367	4.03	0.522	11.09	0.135	6.27	0.412	7.23	0.641	8.22	0.327
11.48	0.394	4.37	0.515	11.33	0.174	6.28	0.609	7.25	0.625	8.26	0.368
11.56	0.394	4.74	0.488	11.49	0.208	6.28	0.630	7.25	0.605	8.26	0.491
11.92	0.263	4.95	0.488	11.65	0.208	6.31	0.641	7.26	0.620	8.28	0.511
12.37	0.136	5.28	0.465	11.77	0.192	6.33	0.627	7.29	0.642	8.32	0.496
12.73	0.074	5.49	0.454	11.95	0.154	6.33	0.576	7.32	0.670	8.32	0.458
12.83	0.057	5.80	0.378	12.31	0.150	6.39	0.586	7.36	0.650	8.34	0.457
13.01	0.095	5.95	0.401	12.47	0.104	6.39	0.755	7.36	0.620	8.35	0.425
13.22	0.163	6.09	0.373	12.73	0.099	6.45	0.784	7.37	0.572	8.35	0.380
13.37	0.221	6.26	0.399	12.90	0.099	6.49	0.756	7.38	0.602	8.38	0.329
13.50	0.198	6.26	0.417	13.04	0.119	6.50	0.602	7.41	0.627	8.39	0.268
13.61	0.154	6.39	0.436	13.50	0.177	6.55	0.602	7.41	0.676	8.40	0.225
13.89	0.206	6.60	0.460	13.72	0.177	6.55	0.499	7.46	0.658	8.40	0.186
14.02	0.222	6.87	0.460	13.80	0.253	6.56	0.453	7.51	0.634	8.42	0.164
14.20	0.245	6.96	0.445	13.95	0.268	6.56	0.189	7.55	0.613	8.47	0.193
14.32	0.138	6.99	0.291	14.08	0.303	6.60	0.145	7.59	0.579	8.49	0.232
14.41	0.179	7.00	0.412	14.23	0.227	6.62	0.192	7.62	0.546	8.49	0.328
14.49	0.405	7.03	0.403	14.39	0.197	6.62	0.316	7.64	0.520	8.49	0.439
14.54	0.465	7.19	0.453	14.50	0.247	6.67	0.316	7.66	0.466	8.51	0.457
14.85	0.481	7.29	0.467	14.59	0.275	6.67	0.388	7.66	0.424	8.54	0.495
14.97	0.518	7.37	0.467	14.76	0.291	6.69	0.451	7.68	0.397	8.59	0.464
		7.47	0.479	14.94	0.301	6.70	0.502	7.70	0.381	8.62	0.435
CURVE 4		7.63	0.479	15.22	0.305	6.75	0.537	7.71	0.347	8.64	0.406
T = 293.		7.73	0.451			6.80	0.516	7.74	0.381	8.68	0.378
		7.83	0.203	CURVE 5		6.80	0.462	7.76	0.431	8.71	0.344
1.85	0.554	7.91	0.292	T = 293.		6.84	0.433	7.78	0.481	8.71	0.316
1.97	0.551	8.00	0.315			6.[illegible]0	0.452	7.81	0.446	8.73	0.287
2.05	0.540	8.06	0.263	5.49	0.841	6.90	0.545	7.84	0.399	8.73	0.243
2.39	0.540	8.16	0.187	5.66	0.841	6.94	0.578	7.85	0.353	8.75	0.222
2.52	0.554	8.31	0.129	5.72	0.835	6.95	0.609	7.87	0.256	8.80	0.212
2.64	0.554	8.67	0.088	5.83	0.839	6.96	0.649	7.87	0.215	8.86	0.206
2.72	0.512	8.99	0.062	5.96	0.821	7.00	0.636	7.90	0.183	8.93	0.210
2.72	0.406	9.42	0.077	6.06	0.803	7.00	0.558	7.93	0.130	8.94	0.221

TABLE 19-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE	5(CONT.)
8.98	0.227
9.05	0.233
9.18	0.231
9.27	0.231
9.36	0.232
9.43	0.220
9.49	0.184
9.55	0.162
9.59	0.155
9.67	0.172
9.70	0.193
9.74	0.221
9.77	0.235
9.75	0.256
9.80	0.275
9.80	0.300
9.91	0.308
9.92	0.308
9.92	0.357
9.93	0.390
9.96	0.424
9.99	0.443
10.05	0.443
10.09	0.463
10.12	0.507
10.14	0.538
10.15	0.570
10.20	0.592
10.25	0.616
10.30	0.637
10.38	0.649
10.56	0.649
10.59	0.643
10.63	0.634
10.66	0.648
10.70	0.660
10.74	0.674
10.79	0.663
10.84	0.645
10.88	0.640

λ	τ
CURVE	5(CONT.)
10.97	0.653
11.08	0.670
11.19	0.680
11.29	0.685
11.39	0.699
11.47	0.688
11.52	0.672
11.56	0.649
11.58	0.615
11.63	0.584
11.65	0.539
11.70	0.489
11.76	0.438
11.80	0.372
11.84	0.294
11.88	0.232
11.89	0.200
11.92	0.180
11.96	0.165
12.02	0.181
12.09	0.203
12.12	0.238
12.12	0.264
12.15	0.285
12.16	0.314
12.16	0.345
12.21	0.367
12.21	0.396
12.25	0.416
12.29	0.421
12.36	0.415
12.41	0.406
12.50	0.422
12.57	0.453
12.58	0.496
12.68	0.514
12.79	0.515
12.91	0.506
13.07	0.531
13.30	0.586

λ	τ
CURVE	5(CONT.)
13.39	0.549
13.45	0.514
13.53	0.480
13.63	0.518
13.69	0.554
13.73	0.592
13.79	0.623
13.88	0.642
13.96	0.655
13.99	0.655
CURVE 6	
T = 296.	
0.278	0.000
0.291	0.493
0.302	0.657
0.310	0.723
0.329	0.768
0.366	0.794
0.440	0.830
0.498	0.852
0.629	0.878
0.735	0.895
0.843	0.901
0.874	0.877
0.892	0.886
0.901	0.872
0.919	0.894
0.938	0.894
0.965	0.882
1.016	0.882
1.036	0.893
1.100	0.893
1.109	0.874
1.120	0.807
1.138	0.562
1.158	0.750
1.173	0.573
1.182	0.696

λ	τ
CURVE	6(CONT.)
1.192	0.822
1.232	0.822
1.211	0.858
1.224	0.876
1.254	0.876
1.262	0.867
1.271	0.889
1.285	0.875
1.306	0.875
1.324	0.858
1.347	0.751
1.356	0.719
1.356	0.662
1.368	0.654
1.374	0.601
1.382	0.423
1.387	0.380
1.397	0.384
1.408	0.377
1.426	0.458
1.442	0.528
1.470	0.543
1.504	0.528
1.525	0.498
1.546	0.527
1.562	0.541
1.575	0.541
1.586	0.532
1.601	0.525
1.614	0.467
1.617	0.407
1.6[illegible]5	0.349
1.62[illegible]	0.319
1.632	0.308
1.638	0.326
1.642	0.246
1.651	0.261
1.662	0.062
1.668	0.012
1.679	0.012

λ	τ
CURVE	6(CONT.)
1.692	0.024
1.702	0.099
1.713	0.178
1.726	0.099
1.735	0.075
1.741	0.103
1.753	0.212
1.758	0.254
1.770	0.218
1.776	0.297
1.776	0.365
1.793	0.401
1.801	0.396
1.808	0.410
1.815	0.397
1.822	0.359
1.832	0.392
1.837	0.355
1.847	0.469
1.869	0.497
1.880	0.473
1.889	0.390
1.897	0.304
1.904	0.286
1.919	0.370
1.935	0.385
1.951	0.389
1.961	0.408
1.991	0.392
2.003	0.405
2.015	0.378
2.034	0.367
2.058	0.300
2.078	0.304
2.101	0.282
2.109	0.217
2.115	0.223
2.136	0.074
2.139	0.026
2.153	0.000

λ	τ
CURVE	6(CONT.)
2.163	0.019
2.177	0.000
2.187	0.017
2.200	0.013
CURVE 7	
T = 296.	
0.286	0.000
0.300	0.038
0.328	0.551
0.340	0.681
0.352	0.746
0.372	0.782
0.392	0.804
0.423	0.829
0.456	0.847
0.493	0.864
0.552	0.881
0.640	0.897
0.737	0.910
0.773	0.919
0.843	0.919
0.868	0.897
0.886	0.900
0.902	0.884
0.924	0.902
0.946	0.904
0.961	0.838
0.973	0.904
1.005	0.895
1.025	0.895
1.066	0.912
1.096	0.912
1.112	0.895
1.122	0.856
1.131	0.705
1.139	0.672
1.153	0.722
1.167	0.653

TABLE 19-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE	7(CONT.)	CURVE	7(CONT.)	CURVE	8(CONT.)	CURVE	9(CONT.)	CURVE	9(CONT.)	CURVE	9(CONT.)
1.177	0.568	1.793	0.230	3.52	0.073	4.86	0.946	9.83	0.168	14.87	0.861
1.188	0.664	1.811	0.253	3.62	0.099	4.97	0.965	9.96	0.233	14.98	0.888
1.193	0.712	1.821	0.250	3.71	0.119	5.08	0.928	10.02	0.344		
1.204	0.736	1.827	0.275	3.80	0.145	5.16	0.942	10.11	0.565	CURVE 10	
1.229	0.828	1.837	0.275	3.88	0.179	5.25	0.928	10.20	0.742	T = 293.	
1.243	0.865	1.839	0.298	4.05	0.229	5.45	0.940	10.25	0.789		
1.260	0.882	1.864	0.350	4.22	0.288	5.60	0.940	10.35	0.848	0.210	0.000
1.278	0.893	1.875	0.327	4.31	0.316	5.77	0.927	10.45	0.873	0.245	0.013
1.297	0.893	1.887	0.275	4.45	0.351	5.97	0.943	10.69	0.873	0.256	0.040
1.321	0.881	1.893	0.170	4.67	0.350	6.09	0.943	10.96	0.827	0.260	0.050
1.334	0.245	1.901	0.156	4.84	0.330	6.17	0.924	11.18	0.827	0.264	0.040
1.374	0.576	1.952	0.288	4.94	0.302	6.26	0.820	11.33	0.807	0.268	0.010
1.375	0.514	1.979	0.323	5.05	0.269	6.33	0.912	11.47	0.773	0.275	0.000
1.395	0.444	2.005	0.323	5.22	0.193	6.41	0.935	11.55	0.704	0.297	0.000
1.414	0.413	2.018	0.293	5.36	0.206	6.58	0.945	11.85	0.576	0.303	0.016
1.424	0.436	2.087	0.202	5.45	0.252	6.68	0.925	11.95	0.626	0.306	0.031
1.440	0.509	2.108	0.063	5.57	0.236	6.79	0.944	12.09	0.654	0.312	0.045
1.469	0.572	2.131	0.063	5.67	0.054	6.89	0.898	12.22	0.609	0.321	0.054
1.496	0.604	2.131	0.024	5.85	0.035	6.97	0.797	12.29	0.512	0.330	0.061
1.536	0.604	2.143	0.003	5.98	0.042	7.25	0.830	12.45	0.413	0.338	0.076
1.566	0.636	2.157	0.028	6.25	0.071	7.36	0.830	12.55	0.504	0.347	0.133
1.581	0.636	2.167	0.007			7.53	0.776	12.60	0.579	0.354	0.251
1.605	0.627	2.185	0.027	CURVE 9		7.64	0.713	12.74	0.638	0.358	0.323
1.620	0.529	2.200	0.000	T = 296.		7.75	0.713	12.90	0.689	0.360	0.520
1.631	0.427					7.83	0.639	13.09	0.699	0.365	0.783
1.641	0.440	CURVE 8		2.00	0.942	7.95	0.501	13.28	0.754	0.365	0.703
1.643	0.376	T = 296.		2.33	0.942	7.97	0.589	13.39	0.718	0.369	0.817
1.653	0.202			2.44	0.922	7.97	0.788	13.47	0.667	0.373	0.835
1.662	0.050	2.64	0.357	2.56	0.953	8.07	0.858	13.56	0.573	0.381	0.851
1.672	0.022	2.66	0.314	2.67	0.933	8.17	0.858	13.78	0.578	0.399	0.864
1.683	0.037	2.66	0.153	2.78	0.891	8.31	0.776	13.86	0.525	0.404	0.876
1.691	0.032	2.68	0.159	3.01	0.934	8.45	0.702	13.91	0.471	0.417	0.802
1.694	0.050	2.68	0.080	3.20	0.915	8.58	0.420	14.06	0.583	0.435	0.890
1.704	0.063	2.70	0.053	3.25	0.832	8.70	0.212	14.15	0.601	0.459	0.897
1.719	0.058	2.74	0.036	3.17	0.949	8.79	0.103	14.22	0.521	0.484	0.983
1.735	0.058	2.82	0.021	3.38	0.894	9.00	0.103	14.34	0.339	0.512	0.904
1.742	0.105	3.02	0.022	3.49	0.928	9.23	0.117	14.41	0.509	0.548	0.906
1.759	0.153	3.17	0.029	3.70	0.959	9.39	0.101	14.47	0.608	0.600	0.906
1.772	0.147	3.30	0.039	4.03	0.959	9.53	0.101	14.52	0.784	0.630	0.910
1.776	0.183	3.42	0.052	4.42	0.954	9.68	0.130	14.75	0.861	0.655	0.915

TABLE 19-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 10(CONT.)		CURVE 10(CONT.)		CURVE 11		CURVE 11(CONT.)		CURVE 11(CONT.)		CURVE 12(CONT.)	
0.689	0.915	1.652	0.764	T = 293.		1.040	0.940	1.712	0.604	2.64	0.932
0.735	0.910	1.663	0.205	0.240	0.000	1.086	0.935	1.750	0.098	2.70	0.932
0.776	0.910	1.675	0.088	0.245	0.013	1.132	0.937	1.750	0.519	2.78	0.926
0.822	0.916	1.687	0.078	0.256	0.040	1.146	0.932	1.762	0.574	2.93	0.922
0.857	0.920	1.694	0.096	0.260	0.050	1.153	0.848	1.786	0.452	2.95	0.934
0.893	0.921	1.694	0.551	0.264	0.043	1.161	0.860	1.795	0.841	2.97	0.916
0.910	0.897	1.706	0.543	0.268	0.010	1.180	0.567	1.811	0.546	3.00	0.913
0.920	0.911	1.714	0.604	0.275	0.000	1.191	0.597	1.811	0.821	3.03	0.918
0.940	0.922	1.750	0.519	0.287	0.013	1.205	0.880	1.841	0.560	3.17	0.918
0.991	0.928	1.750	0.098	0.296	0.039	1.222	0.890	1.858	0.858	3.20	0.908
1.030	0.916	1.762	0.574	0.303	0.056	1.227	0.917	1.888	0.848	3.25	0.908
1.054	0.926	1.786	0.452	0.310	0.060	1.247	0.914	1.914	0.818	3.27	0.890
1.081	0.933	1.795	0.841	0.324	0.050	1.274	0.935	1.932	0.810	3.30	0.900
1.114	0.933	1.811	0.821	0.332	0.050	1.306	0.918	1.945	0.771	3.34	0.877
1.140	0.920	1.811	0.546	0.338	0.062	1.324	0.931	1.972	0.747	3.36	0.740
1.146	0.866	1.841	0.560	0.347	0.133	1.340	0.931	1.986	0.778	3.37	0.578
1.153	0.848	1.858	0.858	0.354	0.251	1.349	0.913	2.004	0.768	3.39	0.735
1.16	0.860	1.888	0.848	0.358	0.323	1.355	0.870	2.023	0.806	3.41	0.850
1.180	0.567	1.914	0.818	0.360	0.520	1.358	0.742	2.037	0.772	3.45	0.850
1.191	0.597	1.932	0.810	0.360	0.813	1.390	0.749	2.084	0.826	3.45	0.884
1.205	0.880	1.945	0.771	0.370	0.841	1.403	0.638	2.109	0.792	3.51	0.910
1.222	0.890	1.972	0.747	0.382	0.855	1.416	0.703	2.133	0.575	3.55	0.926
1.247	0.898	1.986	0.778	0.391	0.864	1.435	0.847	2.193	0.226	3.58	0.917
1.262	0.903	2.004	0.768	0.404	0.876	1.449	0.880	2.208	0.064	3.61	0.938
1.285	0.882	2.023	0.806	0.417	0.882	1.476	0.872	2.223	0.037	3.74	0.949
1.312	0.891	2.037	0.772	0.435	0.890	1.500	0.872	2.223	0.014	3.77	0.933
1.355	0.870	2.084	0.826	0.459	0.897	1.517	0.833	2.275	0.000	3.87	0.952
1.358	0.742	2.109	0.792	0.484	0.903	1.542	0.820	2.323	0.152	4.02	0.945
1.390	0.741	2.133	0.575	0.512	0.904	1.563	0.852	2.366	0.082	4.17	0.952
1.403	0.638	2.153	0.614	0.548	0.906	1.585	0.808	2.399	0.034	4.22	0.939
1.416	0.703	2.265	0.000	0.600	0.906	1.596	0.906	2.421	0.182	4.27	0.955
1.435	0.847	2.296	0.182	0.647	0.918	1.611	0.906	2.438	0.023	4.32	0.938
1.459	0.871	2.344	0.000	0.690	0.924	1.618	0.887	2.455	0.062	4.38	0.950
1.500	0.857	2.366	0.082	0.782	0.924	1.637	0.772	2.472	0.087	4.51	0.950
1.510	0.824	2.399	0.034	0.826	0.919	1.652	0.764			4.55	0.958
1.531	0.814	2.421	0.182	0.904	0.925	1.663	0.205	CURVE 12		4.63	0.945
1.563	0.852	2.436	0.023	0.912	0.908	1.675	0.088	T = 293.		4.81	0.945
1.585	0.808	2.455	0.062	0.938	0.933	1.687	0.078			5.00	0.954
1.618	0.837	2.472	0.087	0.959	0.937	1.694	0.096	2.50	0.945	5.10	0.950
1.637	0.772			1.007	0.921	1.706	0.543	2.59	0.938	5.19	0.945

TABLE 19-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 12(CONT.)		CURVE 12(CONT.)		CURVE 12(CONT.)		CURVE 13(CONT.)		CURVE 13(CONT.)		CURVE 13(CONT.)	
5.23	0.961	9.17	0.256	21.23	0.862	4.02	0.898	7.62	0.801	14.39	0.660
5.30	0.954	9.33	0.291	22.68	0.728	4.07	0.904	7.71	0.719	14.64	0.683
5.34	0.968	9.51	0.303	23.53	0.648	4.18	0.904	7.79	0.548	14.73	0.725
5.38	0.957	9.63	0.265	25.00	0.621	4.27	0.865	7.85	0.203	15.11	0.725
5.44	0.960	9.74	0.242			4.35	0.903	7.91	0.087	15.24	0.800
5.47	0.944	9.82	0.290	CURVE 13		4.81	0.903	7.96	0.205	15.46	0.815
5.52	0.952	9.95	0.572	T = 293.		4.89	0.891	8.02	0.659	15.80	0.815
5.66	0.952	10.16	0.742			4.96	0.910	8.10	0.761	16.03	0.794
5.86	0.928	10.42	0.826	2.50	0.919	5.00	0.899	8.15	0.798	16.69	0.833
5.92	0.940	10.62	0.842	2.60	0.917	5.03	0.906	8.25	0.813	17.51	0.833
6.23	0.935	11.00	0.798	2.65	0.913	5.07	0.900	8.39	0.785	18.25	0.822
6.26	0.913	11.15	0.759	2.66	0.894	5.12	0.863	8.57	0.669	20.24	0.822
6.31	0.939	11.33	0.654	2.68	0.914	5.19	0.903	8.71	0.501	20.75	0.780
6.41	0.939	11.43	0.606	2.71	0.888	5.23	0.892	8.86	0.226	21.46	0.853
6.53	0.950	11.56	0.591	2.74	0.895	5.27	0.904	8.97	0.128	22.22	0.828
6.67	0.940	11.75	0.614	2.85	0.892	5.42	0.911	9.11	0.083	23.98	0.597
6.78	0.940	11.92	0.542	2.95	0.886	5.56	0.898	9.23	0.083	25.00	0.534
6.94	0.902	12.18	0.298	3.02	0.880	5.61	0.882	9.42	0.105		
7.02	0.865	12.36	0.212	3.09	0.880	5.72	0.882	9.63	0.105	CURVE 14	
7.06	0.831	12.52	0.334	3.13	0.868	5.79	0.790	9.77	0.085	T = 293.	
7.12	0.852	12.77	0.605	3.16	0.877	5.84	0.799	9.91	0.179		
7.15	0.900	12.92	0.666	3.24	0.846	5.92	0.761	10.17	0.602	2.50	0.973
7.22	0.932	12.92	0.693	3.26	0.818	5.97	0.845	10.35	0.713	2.56	0.971
7.37	0.949	13.14	0.706	3.27	0.818	6.05	0.861	10.57	0.754	2.63	0.960
7.51	0.949	13.33	0.737	3.30	0.835	6.13	0.869	10.81	0.754	2.66	0.933
7.64	0.922	13.50	0.702	3.34	0.791	6.29	0.845	10.91	0.713	2.67	0.958
7.71	0.881	13.61	0.776	3.36	0.598	6.36	0.866	11.21	0.650	2.69	0.937
7.76	0.819	13.79	0.794	3.38	0.338	6.50	0.876	11.40	0.500	2.72	0.937
7.82	0.495	14.14	0.681	3.40	0.643	6.67	0.876	11.64	0.426	2.74	0.921
7.88	0.283	14.35	0.780	3.43	0.660	6.79	0.855	11.81	0.457	2.79	0.930
7.96	0.694	14.99	0.814	3.45	0.682	6.94	0.790	12.11	0.166	2.95	0.913
7.99	0.796	15.04	0.869	3.46	0.763	6.98	0.739	12.41	0.066	3.14	0.913
8.05	0.871	15.60	0.873	3.52	0.793	7.03	0.774	12.53	0.091	3.21	0.895
8.18	0.908	15.82	0.860	3.54	0.854	7.07	0.704	12.85	0.498	3.24	0.852
8.34	0.885	16.47	0.889	3.60	0.873	7.14	0.733	13.09	0.615	3.25	0.786
8.49	0.813	17.76	0.889	3.65	0.896	7.17	0.806	13.42	0.662	3.27	0.803
8.61	0.715	18.69	0.901	3.68	0.876	7.26	0.832	13.62	0.594	3.28	0.765
8.73	0.595	19.27	0.886	3.71	0.904	7.32	0.859	13.87	0.730	3.29	0.817
8.82	0.442	19.76	0.886	3.77	0.881	7.42	0.859	14.08	0.598	3.34	0.800
8.98	0.299	20.24	0.836	3.84	0.898	7.53	0.832	14.22	0.564	3.37	0.544

TABLE 19-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 14 (CONT.)		CURVE 14 (CONT.)		CURVE 14 (CONT.)		CURVE 14 (CONT.)		CURVE 15 (CONT.)		CURVE 15 (CONT.)	
3.38	0.455	5.92	0.908	9.72	0.162	22.73	0.748	4.57	0.973	8.30	0.838
3.40	0.758	6.05	0.908	9.80	0.188	23.42	0.666	5.00	0.974	8.41	0.765
3.42	0.784	6.17	0.888	10.07	0.567	23.70	0.599	5.11	0.945	8.50	0.708
3.45	0.770	6.20	0.868	10.31	0.732	24.21	0.589	5.19	0.973	8.70	0.342
3.46	0.834	6.26	0.809	10.45	0.756	25.00	0.595	5.32	0.950	8.77	0.232
3.47	0.868	6.29	0.867	10.65	0.695			5.36	0.970	8.77	0.176
3.50	0.882	6.37	0.896	10.79	0.711	CURVE 15		5.42	0.970	8.90	0.156
3.54	0.909	6.52	0.910	10.94	0.650	T = 293.		5.51	0.939	8.99	0.171
3.57	0.909	6.63	0.910	11.12	0.662			5.59	0.963	9.29	0.140
3.61	0.940	6.67	0.879	11.30	0.560	2.49	0.972	5.65	0.944	9.46	0.156
3.65	0.940	6.76	0.879	11.75	0.418	2.50	0.972	5.69	0.956	9.61	0.287
3.66	0.931	6.90	0.812	11.96	0.342	2.65	0.971	5.87	0.924	9.82	0.203
3.71	0.941	6.93	0.812	12.14	0.257	2.79	0.962	5.93	0.948	9.96	0.228
3.74	0.921	6.97	0.695	12.36	0.148	2.96	0.950	6.06	0.938	10.13	0.601
3.78	0.943	7.01	0.781	12.56	0.208	3.06	0.937	6.13	0.951	10.24	0.761
4.02	0.943	7.08	0.715	12.99	0.567	3.17	0.921	6.23	0.926	10.37	0.819
4.16	0.956	7.13	0.750	13.21	0.630	3.19	0.900	6.28	0.788	10.66	0.866
4.22	0.922	7.19	0.813	13.40	0.623	3.22	0.915	6.31	0.910	10.87	0.877
4.24	0.935	7.24	0.798	13.62	0.645	3.25	0.887	6.39	0.947	11.26	0.877
4.28	0.925	7.26	0.837	13.79	0.595	3.27	0.741	6.53	0.957	11.43	0.851
4.33	0.947	7.43	0.680	14.01	0.595	3.28	0.813	6.70	0.946	11.72	0.687
4.42	0.942	7.55	0.851	14.22	0.500	3.29	0.762	6.73	0.897	11.82	0.655
4.46	0.930	7.68	0.806	14.45	0.691	3.30	0.843	6.73	0.923	11.57	0.672
4.55	0.944	7.76	0.752	14.66	0.734	3.33	0.810	6.78	0.933	12.18	0.656
4.59	0.906	7.84	0.483	14.97	0.701	3.36	0.865	6.86	0.896	12.42	0.380
4.79	0.935	7.91	0.195	15.11	0.758	3.39	0.700	6.92	0.911	12.59	0.404
4.98	0.946	7.99	0.580	15.36	0.785	3.41	0.814	6.96	0.902	12.72	0.395
5.00	0.947	8.05	0.768	15.53	0.751	3.43	0.747	7.00	0.518	12.99	0.502
5.07	0.942	8.17	0.810	15.65	0.795	3.47	0.897	7.03	0.840	13.40	0.616
5.13	0.920	8.30	0.810	16.05	0.803	3.50	0.887	7.06	0.861	13.66	0.444
5.26	0.938	8.42	0.758	16.29	0.833	3.51	0.839	7.14	0.831	13.85	0.596
5.29	0.928	8.49	0.717	16.95	0.816	3.51	0.836	7.19	0.883	14.03	0.662
5.32	0.948	8.66	0.580	17.33	0.794	3.53	0.928	7.33	0.936	14.35	0.403
5.36	0.955	8.74	0.355	18.45	0.811	3.62	0.951	7.43	0.946	14.58	0.822
5.42	0.944	8.80	0.361	18.94	0.572	3.78	0.963	7.76	0.902	14.99	0.859
5.46	0.926	8.99	0.213	19.42	0.602	4.02	0.972	7.83	0.833	15.34	0.897
5.62	0.926	9.07	0.180	19.96	0.776	4.25	0.972	7.87	0.460	15.67	0.869
5.73	0.900	9.27	0.163	20.62	0.767	4.30	0.950	7.94	0.385	16.42	0.887
5.80	0.883	9.50	0.190	21.01	0.740	4.40	0.966	8.05	0.854	16.98	0.871
5.87	0.887	9.59	0.173	21.98	0.797	4.50	0.966	8.16	0.884	17.51	0.890

TABLE 19-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ
CURVE 15(CONT.)	
18.45	0.857
18.94	0.835
20.16	0.785
20.62	0.511
21.23	0.584
21.46	0.696
22.03	0.721
23.20	0.592
24.33	0.644
25.00	0.670
CURVE 16	
T = 293.	
1.01	0.895
1.47	0.857
2.00	0.897
2.49	0.679
2.98	0.208
3.48	0.416
3.98	0.648
4.52	0.650
5.00	0.417
5.48	0.226
6.04	0.124
6.55	0.098
6.98	0.092
7.48	0.023
7.96	0.000
8.47	0.000
9.01	0.000
9.49	0.000
10.00	0.000
CURVE 17	
T = 293.	
1.00	0.825
1.50	0.838
2.00	0.840

λ	τ
CURVE 17(CONT.)	
2.50	0.678
2.99	0.538
3.51	0.452
4.01	0.631
4.52	0.669
5.01	0.450
5.49	0.238
6.00	0.131
6.51	0.106
6.99	0.059
7.48	0.094
8.02	0.020
8.48	0.004
9.01	0.000
9.49	0.000
10.00	0.000
CURVE 18	
T = 293.	
1.00	0.787
1.49	0.847
1.98	0.853
2.47	0.816
2.98	0.755
3.49	0.736
4.00	0.782
4.49	0.824
4.98	0.728
5.50	0.581
5.97	0.531
6.47	0.469
6.99	0.430
7.49	0.375
7.99	0.194
8.45	0.017
8.97	0.000
9.48	0.000
10.00	0.000

λ	τ
CURVE 19	
T = 293.	
1.00	0.787
1.49	0.847
1.98	0.853
2.49	0.707
2.99	0.505
3.49	0.453
3.95	0.609
4.47	0.655
5.00	0.529
5.51	0.198
6.00	0.077
6.47	0.097
6.99	0.021
7.49	0.021
7.99	0.009
8.49	0.006
8.97	0.000
9.48	0.000
10.00	0.000
CURVE 20	
T = 293.	
2.00	0.955
2.22	0.955
2.32	0.941
2.43	0.947
2.72	0.947
3.15	0.936
3.27	0.925
3.30	0.904
3.35	0.598
3.37	0.575
3.40	0.606
3.41	0.654
3.45	0.650
3.48	0.863
3.53	0.892
3.58	0.918

λ	τ
CURVE 20(CONT.)	
3.68	0.936
3.80	0.950
4.40	0.950
4.97	0.940
5.12	0.948
5.24	0.932
5.43	0.932
5.50	0.924
5.74	0.937
6.13	0.937
6.35	0.930
6.41	0.943
6.57	0.943
6.66	0.932
6.72	0.893
6.78	0.785
6.81	0.707
6.84	0.764
6.86	0.849
6.88	0.892
6.92	0.909
6.99	0.876
7.04	0.781
7.08	0.868
7.12	0.907
7.19	0.907
7.23	0.900
7.29	0.931
7.54	0.938
7.71	0.907
7.81	0.878
7.86	0.824
7.93	0.492
7.96	0.465
7.99	0.500
8.02	0.658
6.04	0.693
8.10	0.697
8.15	0.774
8.19	0.799

λ	τ
CURVE 20(CONT.)	
8.26	0.757
8.37	0.649
8.47	0.476
8.54	0.351
8.62	0.262
8.72	0.194
8.81	0.154
8.86	0.132
8.93	0.132
9.01	0.173
9.14	0.265
9.21	0.306
9.30	0.325
9.38	0.296
9.47	0.245
9.56	0.227
9.62	0.255
9.71	0.328
9.77	0.356
9.81	0.339
9.87	0.272
9.93	0.347
10.02	0.517
10.07	0.625
10.15	0.695
10.24	0.716
10.30	0.700
10.36	0.625
10.41	0.647
10.46	0.747
10.55	0.826
10.60	0.845
10.72	0.877
10.84	0.891
11.00	0.895
10.56	0.821
10.60	0.851
10.69	0.875
10.79	0.889
10.90	0.899

λ	τ
CURVE 20(CONT.)	
11.22	0.899
11.50	0.919
11.67	0.934
12.01	0.934
12.31	0.925
12.41	0.910
12.50	0.868
12.57	0.805
12.66	0.758
12.76	0.723
12.89	0.687
13.01	0.654
13.15	0.586
13.25	0.533
13.35	0.514
13.49	0.576
13.68	0.686
13.75	0.737
13.83	0.775
13.97	0.808
14.05	0.783
14.12	0.742
14.18	0.698
14.25	0.600
14.32	0.514
14.39	0.487
14.47	0.524
14.55	0.605
14.62	0.681
14.68	0.725
14.74	0.755
14.79	0.771
14.91	0.782
15.00	0.815
CURVE 21	
T = 293.	
2.00	0.953
2.46	0.944

TABLE 19-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, ; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 21 (CONT.)		CURVE 21 (CONT.)		CURVE 21 (CONT.)		CURVE 21 (CONT.)		CURVE 22 (CONT.)		CURVE 22 (CONT.)	
2.54	0.962	6.28	0.905	9.53	0.104	13.05	0.726	4.42	0.903	8.19	0.849
2.63	0.962	6.47	0.960	9.74	0.116	13.11	0.766	4.47	0.863	8.29	0.831
2.68	0.951	6.62	0.960	9.86	0.161	13.17	0.782	4.50	0.798	8.38	0.791
2.74	0.898	6.70	0.927	9.93	0.316	13.25	0.782	4.59	0.324	8.52	0.686
2.84	0.931	6.78	0.959	9.97	0.400	13.33	0.738	4.61	0.272	8.67	0.514
2.96	0.938	6.89	0.943	10.03	0.332	13.49	0.565	4.63	0.320	8.88	0.256
3.04	0.952	6.93	0.918	10.07	0.525	13.61	0.599	4.66	0.595	8.96	0.192
3.18	0.952	6.95	0.564	10.10	0.638	13.75	0.599	4.69	0.844	9.07	0.154
3.21	0.896	6.98	0.525	10.19	0.762	13.81	0.563	4.72	0.884	9.17	0.154
3.26	0.820	6.99	0.787	10.26	0.806	13.89	0.503	4.76	0.913	9.27	0.182
3.29	0.841	7.02	0.806	10.34	0.844	13.93	0.486	4.80	0.925	9.49	0.182
3.33	0.901	7.12	0.819	10.44	0.872	14.00	0.544	4.87	0.925	9.57	0.209
3.37	0.859	6.66	0.838	10.50	0.884	14.06	0.616	4.92	0.915	9.64	0.281
3.40	0.930	7.30	0.851	10.70	0.884	14.11	0.638	4.98	0.930	9.67	0.334
3.45	0.933	7.40	0.851	10.75	0.869	14.16	0.606	5.05	0.924	9.72	0.440
3.50	0.957	7.48	0.832	10.90	0.855	14.29	0.385	5.09	0.870	9.73	0.529
3.55	0.969	7.58	0.835	11.00	0.858	14.34	0.337	5.11	0.917	9.86	0.640
3.92	0.977	7.65	0.819	11.05	0.862	14.38	0.389	5.15	0.930	9.93	0.692
4.45	0.969	7.72	0.830	11.21	0.851	14.45	0.690	5.28	0.930	10.02	0.754
4.85	0.955	7.76	0.812	11.33	0.833	14.49	0.760	5.49	0.915	10.11	0.782
4.99	0.961	7.86	0.551	11.44	0.808	14.55	0.820	5.82	0.915	10.21	0.808
5.06	0.935	7.90	0.510	11.53	0.757	14.65	0.853	6.07	0.900	10.40	0.808
5.11	0.935	7.93	0.537	11.67	0.654	14.81	0.887	6.24	0.914	10.52	0.774
5.15	0.952	7.96	0.722	11.80	0.570	15.00	0.907	6.70	0.914	10.60	0.721
1.21	0.953	7.98	0.854	11.84	0.550			6.92	0.902	10.66	0.657
5.27	0.925	8.03	0.886	11.91	0.612	CURVE 22		7.02	0.874	10.72	0.550
5.33	0.950	8.07	0.897	12.00	0.673	T = 293.		7.09	0.834	10.76	0.494
5.39	0.950	8.15	0.897	12.05	0.666			7.21	0.891	10.78	0.468
5.45	0.925	8.23	0.869	12.16	0.666	2.00	0.927	7.48	0.888	10.84	0.445
5.51	0.950	8.30	0.826	12.23	0.610	2.25	0.932	7.61	0.878	10.88	0.445
5.54	0.950	8.35	0.753	12.32	0.502	2.65	0.932	7.75	0.846	10.92	0.460
5.61	0.933	8.38	0.718	12.42	0.405	3.29	0.917	7.82	0.794	10.96	0.460
5.68	0.951	8.45	0.689	12.51	0.492	3.32	0.900	7.87	0.515	11.00	0.424
5.91	0.951	8.51	0.492	12.60	0.602	3.36	0.787	7.98	0.368	11.02	0.350
6.00	0.938	8.57	0.337	12.65	0.641	3.40	0.903	7.92	0.238	11.09	0.260
6.04	0.953	8.66	0.197	12.70	0.667	3.44	0.912	7.94	0.392	11.15	0.203
6.14	0.947	8.77	0.070	12.79	0.680	3.51	0.925	7.98	0.704	11.18	0.179
6.20	0.924	8.86	0.070	12.86	0.703	4.17	0.930	8.00	0.766	11.24	0.179
6.22	0.896	8.95	0.088	12.92	0.703	4.28	0.922	8.03	0.815	11.37	0.225
6.24	0.801	9.36	0.083	12.98	0.726	4.36	0.927	8.09	0.849	11.42	0.236

TABLE 19-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 22(CONT.)		CURVE 23(CONT.)		CURVE 23(CONT.)		CURVE 23(CONT.)		CURVE 23(CONT.)		CURVE 24(CONT.)	
11.83	0.162	2.77	0.691	5.80	0.929	8.64	0.738	15.43	0.314	3.70	0.837
11.93	0.141	2.81	0.718	5.92	0.697	8.69	0.643	15.62	0.257	3.97	0.906
11.98	0.203	2.84	0.716	5.97	0.897	8.73	0.620	15.82	0.245	4.15	0.947
12.05	0.453	2.89	0.707	6.04	0.919	8.73	0.587	16.10	0.271	4.24	0.955
12.12	0.507	2.93	0.707	6.11	0.919	8.87	0.552	16.58	0.240	4.30	0.973
12.17	0.656	3.01	0.732	6.22	0.900	9.01	0.500	16.95	0.237	4.86	1.000
12.24	0.698	3.07	0.724	6.29	0.907	9.12	0.298	18.55	0.172	5.06	0.927
12.37	0.731	3.18	0.749	6.34	0.924	9.18	0.207	18.94	0.140	5.14	0.933
12.52	0.730	3.23	0.755	6.40	0.937	9.27	0.177	22.32	0.139	5.17	0.927
12.62	0.699	3.28	0.753	6.48	0.937	9.27	0.140	22.83	0.132	5.27	0.939
12.67	0.664	3.32	0.746	6.57	0.922	9.40	0.121	25.00	0.126	5.34	0.946
12.73	0.602	3.36	0.654	6.65	0.902	9.55	0.118			5.38	0.963
12.81	0.492	3.39	0.568	6.71	0.902	9.67	0.095	CURVE 24		5.41	0.943
12.92	0.333	3.40	0.652	6.79	0.911	9.81	0.088	T = 293.		5.44	0.959
12.97	0.294	3.43	0.641	6.86	0.911	9.92	0.067			5.52	0.956
13.02	0.294	3.45	0.690	6.96	0.899	10.07	0.045	2.50	0.540	5.58	0.978
13.14	0.390	3.47	0.715	7.08	0.876	10.18	0.060	2.53	0.539	5.64	0.961
13.25	0.495	3.51	0.706	7.16	0.886	10.45	0.309	2.57	0.555	5.67	0.975
13.34	0.614	3.53	0.755	7.25	0.803	10.67	0.498	2.60	0.556	5.71	0.947
13.46	0.746	3.59	0.787	7.32	0.873	10.87	0.584	2.64	0.569	5.74	0.979
13.57	0.780	3.65	0.811	7.40	0.897	11.06	0.596	2.66	0.578	5.78	0.952
13.71	0.804	3.70	0.828	7.48	0.876	11.35	0.606	2.69	0.568	5.83	0.919
13.89	0.804	3.78	0.822	7.53	0.876	11.53	0.627	2.71	0.555	5.86	0.971
14.04	0.802	3.94	0.860	7.58	0.863	11.64	0.614	2.75	0.593	5.88	0.944
14.49	0.874	4.06	0.845	7.66	0.872	11.76	0.505	2.80	0.597	5.91	0.971
14.86	0.932	4.08	0.845	7.72	0.863	11.88	0.436	2.83	0.607	5.95	0.954
15.00	0.948	4.27	0.833	7.82	0.860	12.03	0.509	2.88	0.607	5.97	0.934
		4.39	0.833	7.88	0.873	12.33	0.498	2.91	0.603	6.00	0.963
CURVE 23		4.53	0.876	7.97	0.623	12.50	0.252	3.01	0.610	6.02	0.916
T = 293.		4.65	0.862	7.99	0.552	12.76	0.091	3.06	0.623	6.03	0.930
		4.90	0.877	8.05	0.241	12.97	0.057	3.13	0.656	6.06	0.866
2.50	0.673	5.00	0.880	8.08	0.206	13.07	0.085	3.26	0.703	6.11	0.938
2.54	0.682	5.17	0.890	8.10	0.247	13.18	0.240	3.34	0.726	6.12	0.882
2.57	0.693	5.31	0.915	8.14	0.687	13.37	0.396	3.37	0.719	6.15	0.910
2.60	0.677	5.44	0.923	8.16	0.788	13.62	0.409	3.40	0.591	6.18	0.895
2.62	0.677	5.50	0.938	8.24	0.839	13.79	0.453	3.43	0.670	6.22	0.913
2.63	0.698	5.54	0.938	8.31	0.852	14.03	0.470	3.45	0.646	6.22	0.893
2.66	0.709	5.65	0.911	8.39	0.842	14.35	0.446	3.50	0.723	6.24	0.919
2.69	0.709	5.69	0.911	8.42	0.809	14.66	0.365	3.54	0.718	6.26	0.892
2.74	0.691	5.73	0.929	8.55	0.795	15.04	0.338	3.55	0.773	6.29	0.921

TABLE 19-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ]

λ	τ	λ	τ	λ	τ	λ	τ	λ	τ	λ	τ
CURVE 24(CONT.)		CURVE 24(CONT.)		CURVE 24(CONT.)		CURVE 25		CURVE 25(CONT.)		CURVE 26(CONT.)	
						T = 293.					
6.34	0.921	7.81	0.884	11.90	0.481			7.60	0.948	3.43	0.916
6.36	0.940	7.87	0.699	12.05	0.506	2.86	0.792	7.70	0.914	3.47	0.923
6.41	0.949	7.93	0.885	12.14	0.497	2.89	0.798	7.78	0.580	3.55	0.972
6.44	0.926	7.99	0.842	12.22	0.497	3.00	0.792	7.84	0.442	4.45	0.976
6.46	0.960	8.06	0.322	12.36	0.486	3.06	0.801	7.89	0.527	4.60	0.977
6.49	0.940	8.08	0.250	12.48	0.216	3.15	0.801	7.99	0.802	5.59	0.979
6.51	0.960	8.13	0.385	12.67	0.141	3.25	0.821	8.07	0.837	5.67	0.948
6.54	0.929	5.17	0.719	12.82	0.085	3.31	0.821	8.18	0.860	5.77	0.825
6.56	0.974	8.22	0.743	12.94	0.070	3.34	0.802	8.33	0.840	5.84	0.803
6.60	0.939	8.28	0.622	13.05	0.155	3.37	0.643	8.58	0.670	5.96	0.385
6.64	0.981	8.35	0.670	13.16	0.282	3.38	0.732	9.43	0.147	6.06	0.932
6.67	0.957	8.48	0.805	13.40	0.394	3.40	0.783	9.54	0.133	6.25	0.950
6.69	0.980	8.62	0.788	13.64	0.404	3.41	0.806	9.73	0.200	6.35	0.981
6.76	0.986	8.70	0.759	13.85	0.448	3.44	0.785	10.47	0.626	6.54	0.981
6.82	0.983	8.79	0.583	14.03	0.463	3.47	0.831	10.68	0.657	6.77	0.943
6.85	0.993	8.92	0.550	14.27	0.444	3.53	0.839	10.93	0.638	7.00	0.899
6.89	0.974	9.06	0.444	14.60	0.360	3.53	0.857	11.26	0.648	7.11	0.845
6.90	0.923	9.12	0.292	14.90	0.324	4.44	0.932	11.53	0.564	7.26	0.914
6.93	0.948	9.25	0.196	15.29	0.306	4.51	0.938	11.71	0.484	7.36	0.884
6.93	0.913	9.25	0.156	15.60	0.242	4.60	0.927	11.98	0.570	7.50	0.941
6.99	0.896	9.40	0.115	15.97	0.263	4.69	0.927	12.22	0.537	7.64	0.941
7.01	0.915	9.56	0.115	16.26	0.251	4.76	0.947	12.41	0.477	7.77	0.848
7.04	0.897	9.68	0.090	17.12	0.186	4.82	0.947	12.64	0.526	7.84	0.617
7.07	0.916	9.89	0.078	18.02	0.170	4.97	0.985	14.10	0.973	7.89	0.562
7.08	0.880	10.03	0.053	18.45	0.152	5.21	0.978			7.96	0.536
7.13	0.903	10.19	0.068	18.90	0.124	5.50	0.982	CURVE 26		8.07	0.826
7.19	0.856	10.27	0.151	19.34	0.136	5.71	0.945	T = 293.		8.18	0.660
7.23	0.885	10.25	0.190	19.88	0.129	5.87	0.974			8.33	0.841
7.27	0.876	10.43	0.249	20.49	0.137	6.00	0.956	2.84	0.746	9.65	0.100
7.34	0.915	10.48	0.336	21.19	0.131	6.14	0.956	2.87	0.690	9.80	0.078
7.39	0.896	10.62	0.376	21.55	0.138	6.23	0.967	2.89	0.665	9.96	0.109
7.41	0.864	10.71	0.477	22.05	0.138	6.46	1.000	2.91	0.657	10.44	0.624
7.44	0.875	10.79	0.532	22.88	0.118	6.61	1.000	2.96	0.658	10.54	0.533
7.46	0.890	11.11	0.596	23.87	0.090	6.76	0.949	3.15	0.849	10.71	0.620
7.50	0.874	11.27	0.569	23.87	0.079	6.90	0.939	3.30	0.508	10.93	0.624
7.52	0.891	11.35	0.529	25.00	0.072	7.00	0.858	3.35	0.908	11.24	0.603
7.59	0.901	11.36	0.601			7.06	0.899	3.36	0.880	11.61	0.551
7.63	0.875	11.57	0.622			7.17	0.924	3.39	0.823	11.98	0.561
7.69	0.879	11.71	0.582			7.35	0.908	3.40	0.858	12.39	0.485
7.73	0.863	11.81	0.501			7.46	0.948	3.40	0.894	12.69	0.551

TABLE 19-12. EXPERIMENTAL NORMAL SPECTRAL TRANSMITTANCE OF SILICON RESIN (WAVELENGTH DEPENDENCE) (CONTINUED)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; TRANSMITTANCE, τ)

λ	τ
CURVE 26(CONT.)	
12.95	0.611
13.04	0.710
13.44	0.815
14.20	1.000

4.20. Aluminized Grafoil

Aluminized grafoil is made by applying thin coatings of aluminum on grafoil, a pure flexible, insulating graphite tape with highly directional properties similar to those of pyrolytic graphite.

The grafoil adds the advantage of flexibility to the thermal-insulating properties of pyrolytic graphite from the cryogenic range up to about 4000 K. Preliminary values of the ratio of the thermal conductivity perpendicular to the surface plane to that along the surface range between 0.001 to 0.006, depending upon the type of grafoil tape measured. There is no increase in thermal conductivity at high temperatures as found in conventional insulation materials. Grafoil tape and foil are normally produced in the 1.0 to 1.3 g cm^{-3} density range. It can be embossed, wrapped, rolled, pressed or otherwise formed.

Aluminized grafoil was made primarily for the purpose of providing a high-reflectivity, low thermal-conductivity material for cryogenic applications. However, advantages of this material made it a favorable material in the area of aircraft design and space vehicle construction where heat insulation plays an important role.

Experimental data on the thermal radiative properties of aluminized grafoil were not found in our literature search. This discouraging fact does not prevent us from making a reasonable estimation for the radiative properties because the thin coatings of aluminum are usually thick enough to be opaque to the radiation and are therefore considered as the sole material interacting with the incident radiation. Therefore, the generation of the most probable values on the thermal radiative properties of aluminized grafoil is based on the available data of aluminum.

Literature survey for aluminum revealed an adequate amount of data on the normal spectral emittance, reflectance and absorptance. Measurement information and experimental results obtained in this survey are given in Tables 20-1 to 20-10 and Figures 20-1 to 20-5. By careful review of the tables and figures, one will see that the magnitudes of the thermal radiative properties are very much affected by the surface conditions of the specimens. The literature abounds with examples of test surfaces shown to be very sensitive to methods of preparation, thermal history, and environmental conditions. Despite this awareness, descriptions of test surfaces are generally inadequate because of our modest understanding of the mechanisms or real surface effects and how to properly characterize a surface.

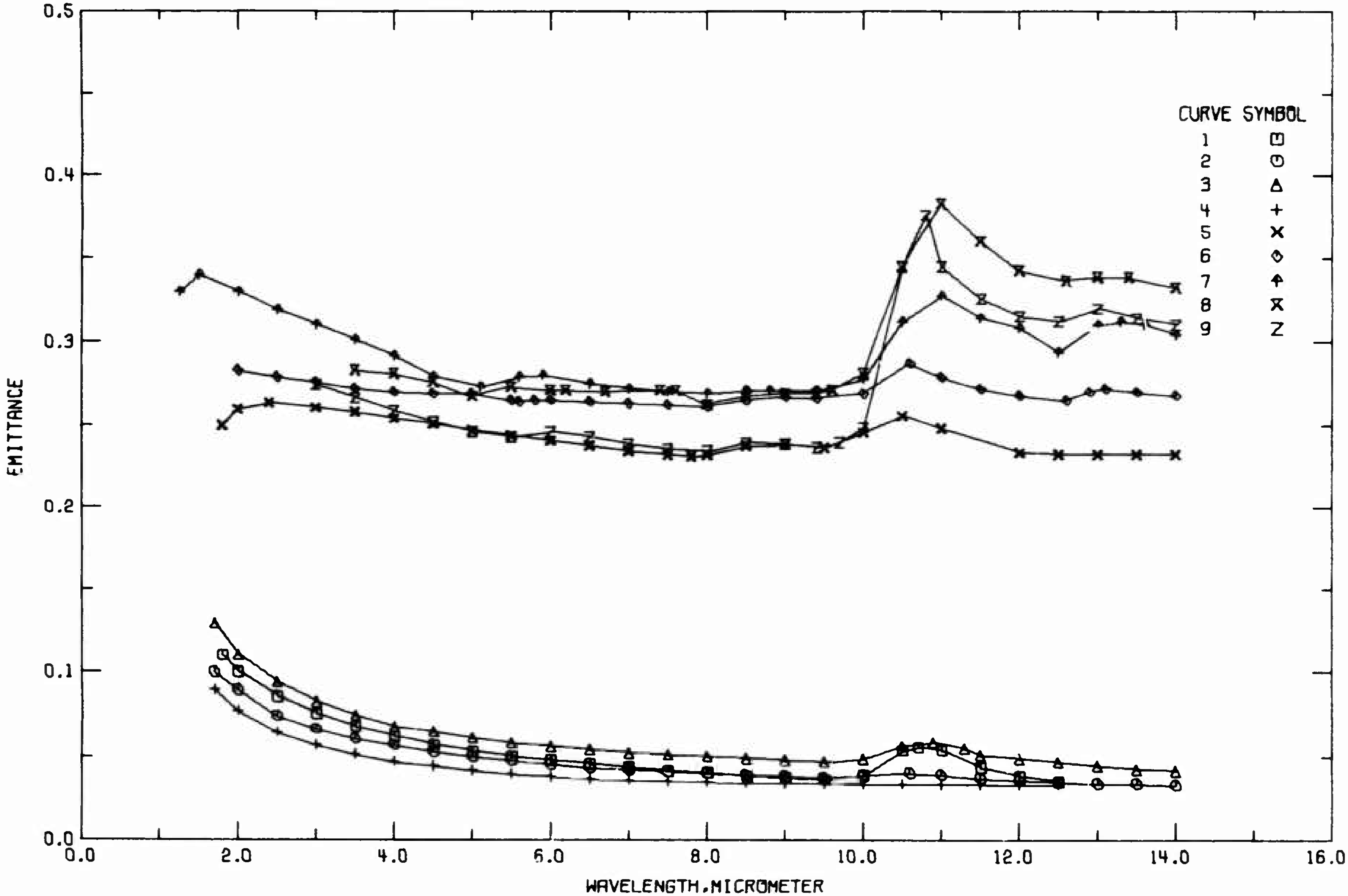


FIGURE 20-1. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM (WAVELENGTH DEPENDENCE).

TABLE 20-1. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T11723	Reynolds, P.M.	1961	1.8-12.5	599		99.7 Al, 0.11 Fe, 0.11 Si, 0.01 Cu, 0.01 Mg, <0.01 Mn, Ni and Zn; cylindrical tube; heated at 467 K for 15 hr; polished with Carmu on Selvyt cloth; surface roughness 0.076 μm (center line average); data extracted from smooth curve; reported error ± 20%.
2	T11723	Reynolds, P.M.	1961	1.7-14.0	697		The above specimen and conditions except heated at 697 K for 20 hr before measurement.
3	T11723	Reynolds, P.M.	1961	1.7-14.0	805		The above specimen and conditions except heated at 805 K for 15 hr before measurement.
4	T11723	Reynolds, P.M.	1961	1.7-12.5	599		The above specimen and conditions.
5	T11723	Reynolds, P.M.	1961	1.8-14.5	462		99.7 Al, 0.11 Fe, 0.11 Si, 0.01 Cu, 0.01 Mg, <0.01 Mn, Ni and Zn; tube; heated for 25 hr at 462 K; roughened and knurled with grade 180 silicon carbide paper; surface roughness 2.92 μm (center line average); data extracted from a smooth curve; error given over the wavelength range 2 to 10 μm, reported error ±10%.
6	T11723	Reynolds, P.M.	1961	2.0-14.0	599		The above specimen and conditions except heated at 598 K for 22 hr before measurement.
7	T11723	Reynolds, P.M.	1961	1.25-14.5	715		The above specimen and conditions except heated at 715 K for 27 hr before measurement.
8	T11723	Reynolds, P.M.	1961	3.5-14.5	803		The above specimen and conditions except heated at 787 K for 17 hr before measurement.
9	T11723	Reynolds, P.M.	1961	3.0-14.0	461		The above specimen and conditions.

TABLE 20-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 1	
T = 599.	
1.8	0.110
2.0	0.100
2.5	0.085
3.0	0.076
3.5	0.065
4.0	0.062
4.5	0.057
5.0	0.053
5.5	0.050
6.0	0.048
6.5	0.045
7.0	0.044
7.5	0.042
8.0	0.041
8.5	0.039
9.0	0.038
9.5	0.037
10.0	0.040
10.5	0.054
10.7	0.056
11.0	0.054
11.5	0.044
12.0	0.039
12.5	0.036
CURVE 2	
T = 697.	
1.7	0.100
2.0	0.090
2.5	0.075
3.0	0.067
3.5	0.061
4.0	0.057
4.5	0.053
5.0	0.050
5.5	0.048
6.0	0.046
6.5	0.044
CURVE 2 (CONT.)	
7.0	0.043
7.5	0.042
8.0	0.041
8.5	0.040
9.0	0.039
9.5	0.038
10.0	0.039
10.6	0.041
11.0	0.040
11.5	0.038
12.0	0.037
12.5	0.035
13.0	0.035
13.5	0.035
14.0	0.034
CURVE 3	
T = 805.	
1.7	0.133
2.0	0.110
2.5	0.094
3.0	0.083
3.5	0.075
4.0	0.068
4.5	0.065
5.0	0.061
5.5	0.058
6.0	0.056
6.5	0.054
7.0	0.052
7.5	0.051
8.0	0.050
8.5	0.049
9.0	0.048
9.5	0.047
10.0	0.049
10.5	0.057
10.9	0.059
11.3	0.055
CURVE 3 (CONT.)	
11.5	0.051
12.0	0.049
12.5	0.047
13.0	0.045
13.5	0.043
14.0	0.042
CURVE 4	
T = 599.	
1.7	0.0900
2.0	0.0760
2.5	0.0630
3.0	0.0563
3.5	0.0515
4.0	0.0470
4.5	0.0446
5.0	0.0420
5.5	0.0400
6.0	0.0386
6.5	0.0372
7.0	0.0365
7.5	0.0360
8.0	0.0355
8.5	0.0348
9.0	0.0347
9.5	0.0346
10.0	0.0345
10.5	0.0344
11.0	0.0343
11.5	0.0342
12.0	0.0341
12.5	0.0341
CURVE 5	
T = 462.	
1.8	0.250
2.0	0.260
2.4	0.264
CURVE 5 (CONT.)	
3.0	0.261
3.5	0.258
4.0	0.254
4.5	0.251
5.0	0.247
5.5	0.244
6.0	0.241
6.5	0.238
7.0	0.235
7.5	0.233
7.8	0.232
8.0	0.233
8.5	0.236
9.0	0.239
9.5	0.237
10.0	0.246
10.5	0.256
11.0	0.248
12.0	0.234
12.5	0.233
13.0	0.233
13.5	0.233
14.0	0.233
14.5	0.231
CURVE 6	
T = 599.	
2.0	0.284
2.5	0.280
3.0	0.277
3.5	0.273
4.0	0.271
4.5	0.270
5.0	0.270
5.5	0.266
5.6	0.265
5.8	0.266
6.0	0.266
6.5	0.265
CURVE 6 (CONT.)	
7.0	0.264
7.5	0.263
8.0	0.262
8.5	0.266
9.0	0.263
9.4	0.267
10.0	0.270
10.6	0.288
11.0	0.280
11.5	0.273
12.0	0.269
12.6	0.256
12.9	0.271
13.1	0.273
13.5	0.271
14.0	0.269
CURVE 7	
T = 715.	
1.25	0.330
1.5	0.340
2.0	0.330
2.5	0.319
3.0	0.310
3.5	0.301
4.0	0.292
4.5	0.286
5.1	0.274
5.6	0.280
5.9	0.281
6.5	0.276
7.0	0.273
7.5	0.271
8.0	0.270
8.5	0.272
8.8	0.272
9.4	0.272
10.0	0.279
10.5	0.312
CURVE 7 (CONT.)	
11.0	0.328
11.5	0.314
12.0	0.308
12.5	0.294
13.0	0.310
13.5	0.312
13.6	0.310
14.0	0.304
14.5	0.301
CURVE 8	
T = 803.	
3.5	0.284
4.0	0.282
4.5	0.277
5.0	0.266
5.5	0.274
6.0	0.272
6.2	0.272
6.7	0.271
7.4	0.272
7.6	0.272
8.0	0.263
8.5	0.266
9.0	0.273
9.4	0.270
9.6	0.272
10.0	[illegible]
10.5	0.345
11.0	0.334
11.5	0.360
12.0	0.343
12.6	0.337
13.0	0.339
13.4	0.339
14.0	0.333
14.5	0.328

TABLE 20-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
CURVE 9	
T = 465.	
3.0	0.273
3.5	0.267
4.0	0.259
4.5	0.252
5.0	0.246
5.5	0.243
6.0	0.246
6.5	0.243
7.0	0.239
7.5	0.236
8.0	0.235
8.5	0.240
9.0	0.239
9.4	0.237
9.7	0.240
10.0	0.249
10.5	0.345
10.8	0.377
11.0	0.345
11.5	0.320
12.0	0.315
12.5	0.312
13.0	0.320
13.5	0.314
14.0	0.310

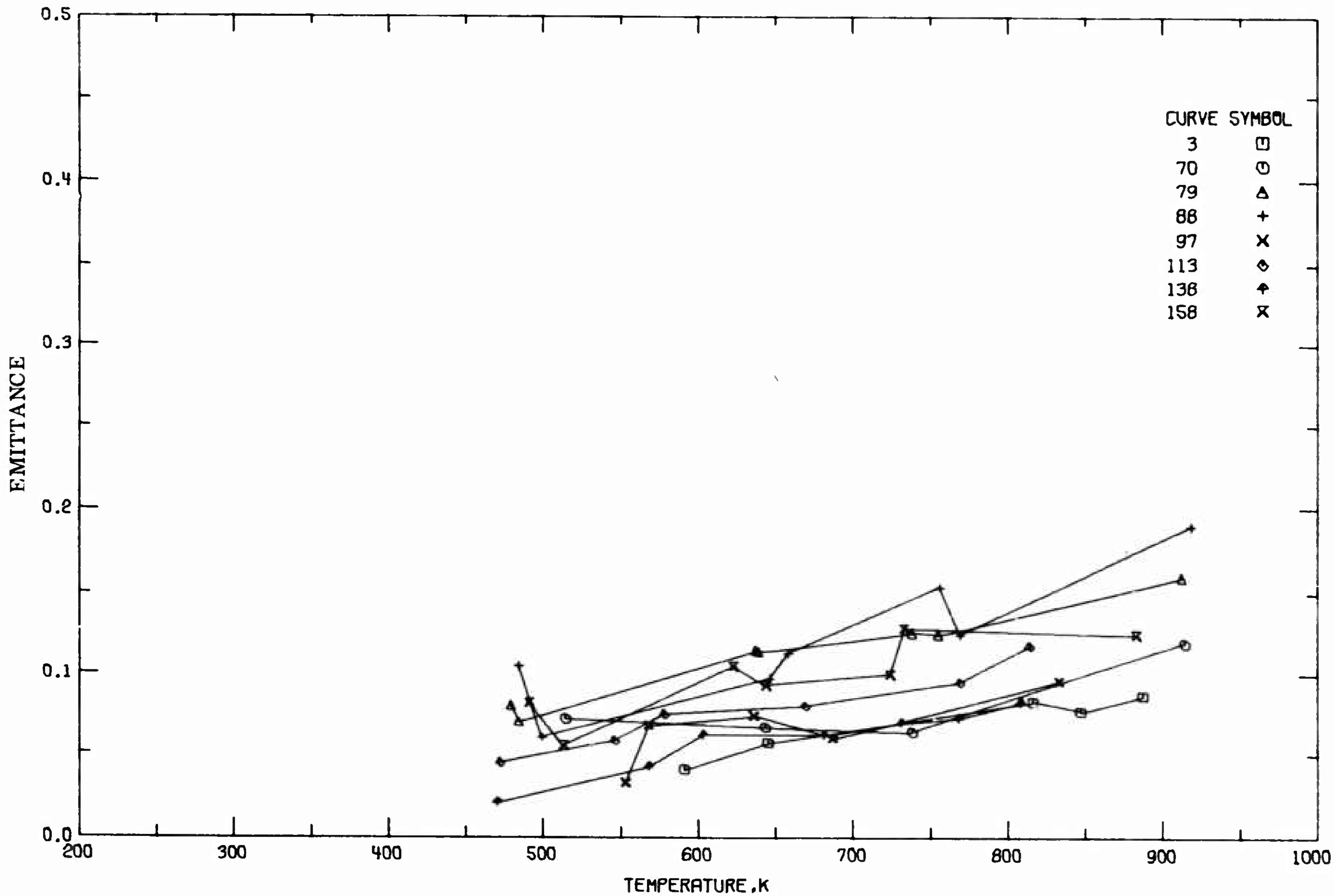


FIGURE 20-2. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM (TEMPERATURE DEPENDENCE).

TABLE 20-3. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T53964	Curcio, J.V.	1968	2.0	591-887	No. 1	99.992 Al, 0.005 Cu, 0.002 Fe, and 0.001 Si; supplied by Alcoa, made from a semi-circular disk about 1.25 in. in diameter and 0.375 in. thick; polished with various grades of emery paper, abraded with 400 alundum for 30 min, and with 600 alundum for 40 min, then oxidized in air at 811 K; reported error 3-8%.
2	T53964	Curcio, J.V.	1968	2.5	591-887	No. 1	The above specimen.
3	T53964	Curcio, J.V.	1968	3.0	591-887	No. 1	The above specimen.
4	T53964	Curcio, J.V.	1968	3.5	591-887	No. 1	The above specimen.
5	T53964	Curcio, J.V.	1968	4.0	591-887	No. 1	The above specimen.
6	T53964	Curcio, J.V.	1968	4.5	591-887	No. 1	The above specimen.
7	T53964	Curcio, J.V.	1968	5.0	591-887	No. 1	The above specimen.
8	T53964	Curcio, J.V.	1968	5.5	591-887	No. 1	The above specimen.
9	T53964	Curcio, J.V.	1968	6.0	591-887	No. 1	The above specimen.
10	T53964	Curcio, J.V.	1968	6.5	591-887	No. 1	The above specimen.
11	T53964	Curcio, J.V.	1968	7.0	645-887	No. 1	The above specimen.
12	T53964	Curcio, J.V.	1968	7.5	645-887	No. 1	The above specimen.
13	T53964	Curcio, J.V.	1968	8.0	645-887	No. 1	The above specimen.
14	T53964	Curcio, J.V.	1968	8.5	645-887	No. 1	The above specimen.
15	T53964	Curcio, J.V.	1968	9.0	645-887	No. 1	The above specimen.
16	T53964	Curcio, J.V.	1968	9.5	816-887	No. 1	The above specimen.
17	T53964	Curcio, J.V.	1968	10.0	816-887	No. 1	The above specimen.
18	T53964	Curcio, J.V.	1968	10.5	816-887	No. 1	The above specimen.
19	T53964	Curcio, J.V.	1968	11.0	816-887	No. 1	The above specimen.
20	T53964	Curcio, J.V.	1968	11.5	816-887	No. 1	The above specimen.
21	T53964	Curcio, J.V.	1968	12.0	816-887	No. 1	The above specimen.
22	T53964	Curcio, J.V.	1968	12.5	816-887	No. 1	The above specimen.
23	T53964	Curcio, J.V.	1968	13.0	816-887	No. 1	The above specimen.
24	T53964	Curcio, J.V.	1968	13.5	816-887	No. 1	The above specimen.
25	T53964	Curcio, J.V.	1968	14.0	816, 887	No. 1	The above specimen.
26	T53964	Curcio, J.V.	1968	2.0	502-888	No. 2	Cut from a disk of the same batch as the above specimen; as received; reported error 3-8%.
27	T53964	Curcio, J.V.	1968	2.5	502-888	No. 2	The above specimen.
28	T53964	Curcio, J.V.	1968	3.0	502-888	No. 2	The above specimen.
29	T53964	Curcio, J.V.	1968	3.5	502-888	No. 2	The above specimen.
30	T53964	Curcio, J.V.	1968	4.0	502-888	No. 2	The above specimen.
31	T53964	Curcio, J.V.	1968	4.5	502-888	No. 2	The above specimen.

TABLE 20-3. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM (Temperature Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
32	T53964	Curcio, J.V.	1968	5.0	502-888	No. 2	The above specimen.
33	T53964	Curcio, J.V.	1968	5.5	502-888	No. 2	The above specimen.
34	T53964	Curcio, J.V.	1968	6.0	502-888	No. 2	The above specimen.
35	T53964	Curcio, J.V.	1968	6.5	502-888	No. 2	The above specimen.
36	T53964	Curcio, J.V.	1968	7.0	502-888	No. 2	The above specimen.
37	T53964	Curcio, J.V.	1968	7.5	502-888	No. 2	The above specimen.
38	T53964	Curcio, J.V.	1968	8.0	502-888	No. 2	The above specimen.
39	T53964	Curcio, J.V.	1968	8.5	502-888	No. 2	The above specimen.
40	T53964	Curcio, J.V.	1968	9.0	502-888	No. 2	The above specimen.
41	T53964	Curcio, J.V.	1968	9.5	502-888	No. 2	The above specimen.
42	T53964	Curcio, J.V.	1968	10.0	502-888	No. 2	The above specimen.
43	T53964	Curcio, J.V.	1968	2.0	617-877	No. 3	Similar to the above specimen; polished with various grades of emery paper; reported error 3-8%.
44	T53964	Curcio, J.V.	1968	2.5	483-877	No. 3	The above specimen.
45	T53964	Curcio, J.V.	1968	3.0	399-877	No. 3	The above specimen.
46	T53964	Curcio, J.V.	1968	3.5	399-877	No. 3	The above specimen.
47	T53964	Curcio, J.V.	1968	4.0	399-877	No. 3	The above specimen.
48	T53964	Curcio, J.V.	1968	4.5	399-877	No. 3	The above specimen.
49	T53964	Curcio, J.V.	1968	5.0	399-877	No. 3	The above specimen.
50	T53964	Curcio, J.V.	1968	5.5	399-877	No. 3	The above specimen.
51	T53964	Curcio, J.V.	1968	6.0	399-877	No. 3	The above specimen.
52	T53964	Curcio, J.V.	1968	6.5	399-877	No. 3	The above specimen.
53	T53964	Curcio, J.V.	1968	7.0	399-877	No. 3	The above specimen.
54	T53964	Curcio, J.V.	1968	7.5	399-877	No. 3	The above specimen.
55	T53964	Curcio, J.V.	1968	8.0	399-877	No. 3	The above specimen.
56	T53964	Curcio, J.V.	1968	8.5	399-877	No. 3	The above specimen.
57	T53964	Curcio, J.V.	1968	9.0	399-877	No. 3	The above specimen.
58	T53964	Curcio, J.V.	1968	9.5	399-877	No. 3	The above specimen.
59	T53964	Curcio, J.V.	1968	10.0	399-877	No. 3	The above specimen.
60	T53964	Curcio, J.V.	1968	10.5	399-877	No. 3	The above specimen.
61	T53964	Curcio, J.V.	1968	11.0	399-877	No. 3	The above specimen.
62	T53964	Curcio, J.V.	1968	11.5	399-877	No. 3	The above specimen.
63	T53964	Curcio, J.V.	1968	12.0	399-877	No. 3	The above specimen.
64	T53964	Curcio, J.V.	1968	12.5	399-877	No. 3	The above specimen.

TABLE 20-3. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM (Temperature Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
65	T53964	Curcio, J.V.	1968	13.0	399-877	No. 3	The above specimen.
66	T53964	Curcio, J.V.	1968	13.5	399-877	No. 3	The above specimen.
67	T53964	Curcio, J.V.	1968	14.0	399-877	No. 3	The above specimen.
68	T53964	Curcio, J.V.	1968	2.0	643-914	No. 4	Similar to the above specimen; polished with various grades of emery paper and abraded with 400 alundum for 5 min; reported error 3-8%.
69	T53964	Curcio, J.V.	1968	2.5	514-914	No. 4	The above specimen.
70	T53964	Curcio, J.V.	1968	3.0	514-914	No. 4	The above specimen.
71	T53964	Curcio, J.V.	1968	3.5	514-914	No. 4	The above specimen.
72	T53964	Curcio, J.V.	1968	4.0	514-914	No. 4	The above specimen.
73	T53964	Curcio, J.V.	1968	4.5	514-914	No. 4	The above specimen.
74	T53964	Curcio, J.V.	1968	5.0	514-914	No. 4	The above specimen.
75	T53964	Curcio, J.V.	1968	5.5	643-914	No. 4	The above specimen.
76	T53964	Curcio, J.V.	1968	6.0	643-914	No. 4	The above specimen.
77	T53964	Curcio, J.V.	1968	2.0	637-912	No. 5	Similar to the above specimen; polished with various grades of emery paper and abraded with 400 alundum for 1 hr; reported error 3-8%.
78	T53964	Curcio, J.V.	1968	2.5	484-912	No. 5	The above specimen.
79	T53964	Curcio, J.V.	1968	3.0	479-912	No. 5	The above specimen.
80	T53964	Curcio, J.V.	1968	3.5	479-912	No. 5	The above specimen.
81	T53964	Curcio, J.V.	1968	4.0	479-912	No. 5	The above specimen.
82	T53964	Curcio, J.V.	1968	4.5	479-912	No. 5	The above specimen.
83	T53964	Curcio, J.V.	1968	5.0	479-912	No. 5	The above specimen.
84	T53964	Curcio, J.V.	1968	5.5	479-912	No. 5	The above specimen.
85	T53964	Curcio, J.V.	1968	6.0	479-912	No. 5	The above specimen.
86	T53964	Curcio, J.V.	1968	2.0	646-918	No. 6	Similar to the above specimen; polished with various grades of emery paper, abraded with 400 alundum for 1 hr and with 600 alundum for 5 min; reported error 3-8%.
87	T53964	Curcio, J.V.	1968	2.5	484-918	No. 6	The above specimen.
88	T53964	Curcio, J.V.	1968	3.0	484-918	No. 6	The above specimen.
89	T53964	Curcio, J.V.	1968	3.5	484-918	No. 6	The above specimen.
90	T53964	Curcio, J.V.	1968	4.0	484-918	No. 6	The above specimen.
91	T53964	Curcio, J.V.	1968	4.5	484-918	No. 6	The above specimen.
92	T53964	Curcio, J.V.	1968	5.0	646-918	No. 6	The above specimen.
93	T53964	Curcio, J.V.	1968	5.5	646-918	No. 6	The above specimen.
94	T53964	Curcio, J.V.	1968	6.0	646-918	No. 6	The above specimen.
95	T53964	Curcio, J.V.	1968	2.0	568-833	No. 7	Similar to the above specimen; polished with various grades of emery paper, abraded with 400 alundum for 30 min and with 600 alundum for 15 min; reported error 3-8%.

TABLE 20-3. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM (Temperature Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
96	T53964	Curcio, J. V.	1968	2.5	568-833	No. 7	The above specimen.
97	T53964	Curcio, J. V.	1968	3.0	553-833	No. 7	The above specimen.
98	T53964	Curcio, J. V.	1968	3.5	553-833	No. 7	The above specimen.
99	T53964	Curcio, J. V.	1968	4.0	553-833	No. 7	The above specimen.
100	T53964	Curcio, J. V.	1968	4.5	553-833	No. 7	The above specimen.
101	T53964	Curcio, J. V.	1968	5.0	553-833	No. 7	The above specimen.
102	T53964	Curcio, J. V.	1968	5.5	553-833	No. 7	The above specimen.
103	T53964	Curcio, J. V.	1968	6.0	553-833	No. 7	The above specimen.
104	T53964	Curcio, J. V.	1968	6.5	636-833	No. 7	The above specimen.
105	T53964	Curcio, J. V.	1968	7.0	687, 833	No. 7	The above specimen.
106	T53964	Curcio, J. V.	1968	7.5	687, 833	No. 7	The above specimen.
107	T53964	Curcio, J. V.	1968	8.0	687, 833	No. 7	The above specimen.
108	T53964	Curcio, J. V.	1968	8.5	687, 833	No. 7	The above specimen.
109	T53964	Curcio, J. V.	1968	9.0	687, 833	No. 7	The above specimen.
110	T53964	Curcio, J. V.	1968	9.5	833	No. 7	The above specimen.
111	T53964	Curcio, J. V.	1968	2.0	546-814	No. 8	Similar to the above specimen; polished with various grades of emery paper, abraded with 400 alundum for 30 min and with 600 alundum for 30 min; reported error 3-8%.
112	T53964	Curcio, J. V.	1968	2.5	472-814	No. 8	The above specimen.
113	T53964	Curcio, J. V.	1968	3.0	472-814	No. 8	The above specimen.
114	T53964	Curcio, J. V.	1968	3.5	472-814	No. 8	The above specimen.
115	T53964	Curcio, J. V.	1968	4.0	472-814	No. 8	The above specimen.
116	T53964	Curcio, J. V.	1968	4.5	472-814	No. 8	The above specimen.
117	T53964	Curcio, J. V.	1968	5.0	472-814	No. 3	The above specimen.
118	T53964	Curcio, J. V.	1968	5.5	472-814	No. 8	The above specimen.
119	T53964	Curcio, J. V.	1968	6.0	472-814	No. 8	The above specimen.
120	T53964	Curcio, J. V.	1968	6.5	472-814	No. 8	The above specimen.
121	T53964	Curcio, J. V.	1968	7.0	546-814	No. 8	The above specimen.
122	T53964	Curcio, J. V.	1968	7.5	546-814	No. 8	The above specimen.
123	T53964	Curcio, J. V.	1968	8.0	578-814	No. 8	The above specimen.
124	T53964	Curcio, J. V.	1968	8.5	578-814	No. 8	The above specimen.
125	T53964	Curcio, J. V.	1968	9.0	669-814	No. 8	The above specimen.
126	T53964	Curcio, J. V.	1968	9.5	669-814	No. 8	The above specimen.
127	T53964	Curcio, J. V.	1968	10.0	769, 814	No. 8	The above specimen.
128	T53964	Curcio, J. V.	1968	10.5	769, 814	No. 8	The above specimen.

TABLE 20-3. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM (Temperature Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
129	T53964	Curcio, J.V.	1968	11.0	769, 814	No. 8	The above specimen.
130	T53964	Curcio, J.V.	1968	11.5	769, 814	No. 8	The above specimen.
131	T53964	Curcio, J.V.	1968	12.0	769, 814	No. 8	The above specimen.
132	T53964	Curcio, J.V.	1968	12.5	769, 814	No. 8	The above specimen.
133	T53964	Curcio, J.V.	1968	13.0	769, 814	No. 8	The above specimen.
134	T53964	Curcio, J.V.	1968	13.5	769, 814	No. 8	The above specimen.
135	T53964	Curcio, J.V.	1968	14.0	769, 814	No. 8	The above specimen.
136	T53964	Curcio, J.V.	1968	2.0	603-808	No. 9	Similar to the above specimen; polished with various grades of emery paper, abraded with 400 alundum for 30 min and with 600 alundum for 30 min; reported error 3-8%.
137	T53964	Curcio, J.V.	1968	2.5	568-808	No. 9	The above specimen.
138	T53964	Curcio, J.V.	1968	3.0	470-808	No. 9	The above specimen.
139	T53964	Curcio, J.V.	1968	3.5	470-808	No. 9	The above specimen.
140	T53964	Curcio, J.V.	1968	4.0	470-808	No. 9	The above specimen.
141	T53964	Curcio, J.V.	1968	4.5	470-808	No. 9	The above specimen.
142	T53964	Curcio, J.V.	1968	5.0	470-808	No. 9	The above specimen.
143	T53964	Curcio, J.V.	1968	5.5	470-808	No. 9	The above specimen.
144	T53964	Curcio, J.V.	1968	6.0	568-808	No. 9	The above specimen.
145	T53964	Curcio, J.V.	1968	6.5	568-808	No. 9	The above specimen.
146	T53964	Curcio, J.V.	1968	7.0	568-808	No. 9	The above specimen.
147	T53964	Curcio, J.V.	1968	7.5	568-808	No. 9	The above specimen.
148	T53964	Curcio, J.V.	1968	8.0	603-808	No. 9	The above specimen.
149	T53964	Curcio, J.V.	1968	8.5	603-808	No. 9	The above specimen.
150	T53964	Curcio, J.V.	1968	9.0	681-808	No. 9	The above specimen.
151	T53964	Curcio, J.V.	1968	9.5	681-768	No. 9	The above specimen.
152	T53964	Curcio, J.V.	1968	10.0	681-768	No. 9	The above specimen.
153	T53964	Curcio, J.V.	1968	10.5	681, 768	No. 9	The above specimen.
154	T53964	Curcio, J.V.	1968	11.0	681, 768	No. 9	The above specimen.
155	T53964	Curcio, J.V.	1968	11.5	681, 768	No. 9	The above specimen.
156	T53964	Curcio, J.V.	1968	2.0	623-883	No. 10	Similar to the above specimen; polished with various grades of emery paper, and abraded with 400 alundum for 1 hr and with 600 alundum for 1 hr; reported error 3-8%.
157	T53964	Curcio, J.V.	1968	2.5	491-883	No. 10	The above specimen.
158	T53964	Curcio, J.V.	1968	3.0	491-883	No. 10	The above specimen.
159	T53964	Curcio, J.V.	1968	3.5	491-883	No. 10	The above specimen.
160	T53964	Curcio, J.V.	1968	4.0	491-883	No. 10	The above specimen.

TABLE 20-3. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL EMITTANCE OF ALUMINUM (Temperature Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
161	T53964	Curcio, J. V.	1968	4.5	513-883	No. 10	The above specimen.
162	T53964	Curcio, J. V.	1968	5.0	513-883	No. 10	The above specimen.
163	T53964	Curcio, J. V.	1968	5.5	623-883	No. 10	The above specimen.
164	T53964	Curcio, J. V.	1968	6.0	623-883	No. 10	The above specimen.
165	T53964	Curcio, J. V.	1968	6.5	644, 883	No. 10	The above specimen.
166	T53964	Curcio, J. V.	1968	7.0	644, 883	No. 10	The above specimen.
167	T53964	Curcio, J. V.	1968	7.5	644, 883	No. 10	The above specimen.
168	T53964	Curcio, J. V.	1968	8.0	644, 883	No. 10	The above specimen.

TABLE 23-4. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ
CURVE 1*	
λ = 2.0	
591.	0.050
645.	0.058
816.	0.100
847.	0.090
887.	0.086
CURVE 2*	
λ = 2.5	
591.	0.050
645.	0.067
816.	0.097
847.	0.084
887.	0.085
CURVE 3	
λ = 3.0	
591.	0.043
645.	0.057
816.	0.083
847.	0.077
887.	0.087
CURVE 4*	
λ = 3.5	
591.	0.040
645.	0.055
816.	0.085
847.	0.075
887.	0.090
CURVE 5*	
λ = 4.0	
591.	0.042
645.	0.054
816.	0.090
CURVE 5(CONT.)*	
847.	0.078
887.	0.087
CURVE 6*	
λ = 4.5	
591.	0.044
645.	0.057
816.	0.090
847.	0.068
887.	0.098
CURVE 7*	
λ = 5.0	
591.	0.043
645.	0.054
816.	0.091
847.	0.070
887.	0.090
CURVE 8*	
λ = 5.5	
591.	0.033
645.	0.044
816.	0.092
847.	0.062
887.	0.090
CURVE 9*	
λ = 6.0	
591.	0.020
645.	0.034
816.	0.085
847.	0.052
887.	0.090
CURVE 10*	
λ = 6.5	
591.	0.005
645.	0.025
816.	0.080
847.	0.048
887.	0.097
CURVE 11*	
λ = 7.0	
645.	0.023
816.	0.087
847.	0.046
887.	0.099
CURVE 12*	
λ = 7.5	
645.	0.020
816.	0.090
847.	0.045
887.	0.100
CURVE 13*	
λ = 8.0	
645.	0.015
816.	0.090
847.	0.042
887.	0.101
CURVE 14*	
λ = 8.5	
645.	0.012
816.	0.093
847.	0.039
887.	0.105
CURVE 15*	
λ = 9.0	
645.	0.037
816.	0.094
847.	0.040
887.	0.107
CURVE 16*	
λ = 9.5	
816.	0.093
847.	0.036
887.	0.107
CURVE 17*	
λ = 10.0	
816.	0.093
847.	0.035
887.	0.110
CURVE 18*	
λ = 10.5	
816.	0.094
847.	0.036
887.	0.112
CURVE 19*	
λ = 11.0	
816.	0.097
847.	0.034
887.	0.118
CURVE 20*	
λ = 11.5	
816.	0.100
847.	0.032
887.	0.116
CURVE 21*	
λ = 12.0	
816.	0.100
847.	0.026
887.	0.115
CURVE 22*	
λ = 12.5	
816.	0.100
847.	0.022
887.	0.116
CURVE 23*	
λ = 13.0	
816.	0.100
847.	0.020
887.	0.116
CURVE 24*	
λ = 13.5	
816.	0.093
847.	[illegible]
887.	0.115
CURVE 25*	
λ = 14.0	
816.	0.093
887.	0.102
CURVE 26*	
λ = 2.0	
502.	0.500
511.	0.514
531.	0.592
596.	0.482
700.	0.570
CURVE 26(CONT.)*	
744.	0.535
888.	0.597
CURVE 27*	
λ = 2.5	
502.	0.535
511.	0.540
581.	0.561
596.	0.455
700.	0.547
744.	0.522
888.	0.602
CURVE 28*	
λ = 3.0	
502.	0.525
511.	0.521
581.	0.550
596.	0.460
700.	0.517
744.	0.553
888.	0.669
CURVE 29*	
λ = 3.5	
502.	0.528
511.	0.516
581.	0.530
591.	0.458
700.	0.502
744.	0.500
888.	0.683
CURVE 30*	
λ = 4.0	
502.	0.495

* NOT SHOWN IN FIGURE.

TABLE 20-4. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM (TEMPERATURE DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ
CURVE 30 (CONT.)*	
511.	0.510
581.	0.520
596.	0.455
700.	0.492
744.	0.487
888.	0.614
CURVE 31* λ = 4.5	
502.	0.510
511.	0.510
581.	0.518
596.	0.455
700.	0.497
744.	0.494
888.	0.586
CURVE 32* λ = 5.0	
502.	0.490
511.	0.535
581.	0.512
596.	0.452
700.	0.497
744.	0.490
888.	0.554
CURVE 33* λ = 5.5	
502.	0.485
511.	0.491
581.	0.508
596.	0.445
700.	0.491
744.	0.490
888.	0.510
CURVE 34* λ = 6.0	
502.	0.462
511.	0.484
581.	0.497
596.	0.450
700.	0.493
744.	0.489
888.	0.506
CURVE 35* λ = 6.5	
502.	0.486
511.	0.465
581.	0.476
596.	0.437
700.	0.485
744.	0.484
888.	0.503
CURVE 36* λ = 7.0	
502.	0.440
511.	0.462
581.	0.471
596.	0.438
700.	0.455
744.	0.475
888.	0.496
CURVE 37* λ = 7.5	
502.	0.449
511.	0.455
581.	0.465
596.	0.430
700.	0.479
744.	0.473
CURVE 37 (CONT.)*	
888.	0.490
CURVE 38* λ = 8.0	
502.	0.433
511.	0.446
581.	0.462
596.	0.428
700.	0.464
744.	0.471
888.	0.490
CURVE 39* λ = 8.5	
502.	0.420
511.	0.440
581.	0.459
596.	0.422
700.	0.484
744.	0.466
888.	0.490
CURVE 40* λ = 9.0	
502.	0.421
511.	0.425
581.	0.447
700.	0.477
744.	0.461
888.	0.487
CURVE 41* λ = 9.5	
502.	0.370
511.	0.407
581.	0.434
CURVE 41 (CONT.)*	
700.	0.470
744.	0.451
888.	0.477
CURVE 42* λ = 10.0	
502.	0.385
511.	0.395
581.	0.424
700.	0.465
744.	0.445
888.	0.477
CURVE 43* λ = 2.0	
617.	0.792
758.	0.770
844.	0.830
877.	0.796
CURVE 44* λ = 2.5	
483.	0.800
617.	0.782
758.	0.768
844.	0.842
877.	0.827
CURVE 45* λ = 3.0	
399.	0.570
483.	0.815
617.	0.783
758.	0.780
844.	0.863
877.	0.880
CURVE 46* λ = 3.5	
399.	0.652
483.	0.793
617.	0.788
758.	0.790
844.	0.872
877.	0.895
CURVE 47* λ = 4.0	
399.	0.643
783.	0.789
617.	0.777
758.	0.791
844.	0.857
877.	0.860
CURVE 48* λ = 4.5	
399.	0.644
483.	0.720
617.	0.773
758.	0.779
844.	0.848
877.	0.840
CURVE 49* λ = 5.0	
399.	0.673
483.	0.776
617.	0.769
758.	0.774
844.	0.836
877.	0.828
CURVE 50* λ = 5.5	
399.	0.672
483.	0.756
617.	0.767
758.	0.774
844.	0.811
877.	0.794
CURVE 51* λ = 6.0	
399.	0.670
483.	0.750
617.	0.757
758.	0.769
844.	0.802
877.	[illegible]
CURVE 52* λ = 6.5	
399.	0.640
483.	0.735
617.	0.746
758.	0.767
844.	0.794
877.	0.783
CURVE 53* λ = 7.0	
399.	0.644
483.	0.722
617.	0.737
758.	0.748
844.	0.790
877.	0.778

* NOT SHOWN IN FIGURE.

TABLE 20-4. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM (TEMPERATURE DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

CURVE 54*
λ = 7.5

T	ε
399.	0.630
483.	0.705
617.	0.722
758.	0.743
844.	0.773
877.	0.755

CURVE 55*
λ = 8.0

T	ε
399.	0.621
483.	0.657
617.	0.715
758.	0.730
844.	0.751
877.	0.741

CURVE 56*
λ = 8.5

T	ε
399.	0.600
483.	0.670
617.	0.700
758.	0.721
844.	0.752
877.	0.732

CURVE 57*
λ = 9.0

T	ε
399.	0.568
483.	0.653
617.	0.681
758.	0.698
844.	0.739
877.	0.718

CURVE 58*
λ = 9.5

T	ε
399.	0.535
483.	0.634
617.	0.659
758.	0.694
844.	0.720
877.	0.708

CURVE 59*
λ = 10.0

T	ε
399.	0.520
483.	0.616
617.	0.653
758.	0.674
844.	0.701
877.	0.685

CURVE 60*
λ = 10.5

T	ε
399.	0.520
483.	0.605
617.	0.642
758.	0.660
844.	0.680
877.	0.666

CURVE 61*
λ = 11.0

T	ε
399.	0.510
483.	0.594
617.	0.632
758.	0.641
844.	0.657
877.	0.640

CURVE 62*
λ = 11.5

T	ε
399.	0.495
483.	0.584
617.	0.617
758.	0.628
844.	0.650
877.	0.632

CURVE 63*
λ = 12.0

T	ε
399.	0.480
483.	0.558
617.	0.593
758.	0.620
844.	0.643
877.	0.624

CURVE 64*
λ = 12.5

T	ε
399.	0.430
483.	0.530
617.	0.574
758.	0.606
844.	0.634
877.	0.623

CURVE 65*
λ = 13.0

T	ε
399.	0.350
483.	0.504
617.	0.557
758.	0.603
844.	0.630
877.	0.615

CURVE 66*
λ = 13.5

T	ε
399.	0.310
483.	0.473
617.	0.577
758.	0.592
844.	0.620
877.	0.603

CURVE 67*
λ = 14.0

T	ε
433.	0.447
617.	0.525
758.	0.572
844.	0.592
877.	0.588

CURVE 68*
λ = 2.0

T	ε
643.	0.109
738.	0.061
914.	0.160

CURVE 69*
λ = 2.5

T	ε
514.	0.104
643.	0.084
738.	0.070
914.	0.135

CURVE 70
λ = 3.0

T	ε
514.	0.072
643.	0.067
738.	0.064
914.	0.120

CURVE 71*
λ = 3.5

T	ε
514.	0.065
643.	0.059
738.	0.056
914.	0.103

CURVE 72*
λ = 4.0

T	ε
514.	0.044
643.	0.050
738.	0.053
914.	0.050

CURVE 73*
λ = 4.5

T	ε
514.	0.034
643.	0.041
738.	0.048
914.	0.076

CURVE 74*
λ = 5.0

T	ε
514.	0.019
643.	0.035
738.	0.045
914.	0.070

CURVE 75*
λ = 5.5

T	ε
643.	0.029
738.	0.042
914.	0.062

CURVE 76*
λ = 6.0

T	ε
643.	0.020
738.	0.036
914.	0.057

CURVE 77*
λ = 2.0

T	ε
637.	0.152
639.	0.158
738.	0.175
755.	0.175
912.	0.202

CURVE 78*
λ = 2.5

T	ε
484.	0.024
637.	0.131
639.	0.126
738.	0.146
755.	0.147
912.	0.174

CURVE 79
λ = 3.0

T	ε
479.	0.080
484.	0.070
637.	0.115
639.	0.114
738.	0.126
755.	0.135
912.	0.160

CURVE 80*
λ = 3.5

T	ε
479.	0.075
484.	0.072

* NOT SHOWN IN FIGURE.

TABLE 20-4. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM (TEMPERATURE DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

T	ε
CURVE 80 (CONT.)*	
637.	0.106
639.	0.106
733.	0.117
755.	0.116
912.	0.153
CURVE 81* λ = 4.0	
479.	0.061
484.	0.057
637.	0.099
639.	0.100
733.	0.103
755.	0.109
912.	0.130
CURVE 82* λ = 4.5	
479.	0.061
484.	0.057
637.	0.099
639.	0.097
733.	0.107
755.	0.103
912.	0.125
CURVE 83* λ = 5.0	
479.	0.053
484.	0.045
637.	0.095
639.	0.095
733.	0.104
755.	0.104
912.	0.120

T	ε
CURVE 84* λ = 5.5	
479.	0.026
484.	0.014
637.	0.082
639.	0.039
733.	0.099
755.	0.092
912.	0.110
CURVE 85* λ = 6.0	
479.	0.011
637.	0.079
639.	0.085
733.	0.091
755.	0.087
912.	0.104
CURVE 86* λ = 2.0	
646.	0.159
658.	0.235
756.	0.243
769.	0.178
918.	0.277
CURVE 87* λ = 2.5	
484.	0.128
493.	[illegible]
646.	0.115
658.	0.156
756.	0.194
769.	0.147
918.	0.240

T	ε
CURVE 88* λ = 3.0	
484.	0.105
493.	0.060
646.	0.097
658.	0.113
756.	0.154
769.	0.125
918.	0.190
CURVE 89* λ = 3.5	
484.	0.080
493.	0.045
646.	0.089
658.	0.106
756.	0.138
769.	0.114
918.	0.152
CURVE 90* λ = 4.0	
484.	0.057
493.	0.010
646.	0.080
658.	0.097
756.	0.130
769.	0.108
918.	0.145
CURVE 91* λ = 4.5	
484.	0.007
646.	0.075
658.	0.093
756.	0.124
769.	0.103
918.	0.129

T	ε
CURVE 92* λ = 5.0	
646.	0.066
658.	0.084
756.	0.116
769.	0.094
918.	0.122
CURVE 93* λ = 5.5	
646.	0.040
658.	0.057
756.	0.099
769.	0.079
918.	0.105
CURVE 94* λ = 6.0	
646.	0.019
658.	0.038
756.	0.080
769.	0.063
918.	0.090
CURVE 95* λ = 2.0	
568.	0.145
636.	0.084
687.	0.036
833.	0.114
CURVE 96* λ = 2.5	
568.	0.095
636.	0.079
687.	0.047
833.	0.114

T	ε
CURVE 97 λ = 3.0	
553.	0.032
568.	0.068
636.	0.074
687.	0.060
833.	0.096
CURVE 98* λ = 3.5	
553.	0.050
568.	0.066
636.	0.075
687.	0.073
833.	0.105
CURVE 99* λ = 4.0	
553.	0.055
568.	0.058
636.	0.078
687.	0.085
833.	0.100
CURVE 100* λ = 4.5	
553.	0.048
568.	0.052
636.	0.067
687.	0.083
833.	0.099
CURVE 101* λ = 5.0	
553.	0.055
568.	0.053
636.	0.070

T	ε
CURVE 101 (CONT.)*	
687.	0.094
833.	0.098
CURVE 102* λ = 5.5	
553.	0.051
568.	0.040
636.	0.055
687.	0.057
833.	0.095
CURVE 103* λ = 6.0	
553.	0.010
568.	0.034
636.	0.033
687.	0.075
833.	0.074
CURVE 104* λ = 6.5	
636.	0.020
687.	0.070
833.	0.072
CURVE 105* λ = 7.0	
687.	0.061
833.	0.055
CURVE 106* λ = 7.5	
687.	0.052
833.	0.043

* NOT SHOWN IN FIGURE.

TABLE 20-4. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM (TEMPERATURE DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

T	ε
CURVE 107*	
λ = 8.0	
687.	0.042
833.	0.035
CURVE 108*	
λ = 8.5	
687.	0.034
833.	0.034
CURVE 109*	
λ = 9.0	
687.	0.007
833.	0.020
CURVE 110*	
λ = 9.5	
833.	0.003
CURVE 111*	
λ = 2.0	
546.	0.014
578.	0.053
669.	0.137
769.	0.135
814.	0.175
CURVE 112*	
λ = 2.5	
472.	0.031
546.	0.059
578.	0.082
669.	0.112
769.	0.131
814.	0.140
CURVE 113	
λ = 3.0	
472.	0.044
546.	0.058
578.	0.075
669.	0.080
769.	0.095
814.	0.118
CURVE 114*	
λ = 3.5	
472.	0.061
546.	0.056
578.	0.055
669.	0.074
769.	0.096
814.	0.116
CURVE 115*	
λ = 4.0	
472.	0.059
546.	0.055
578.	0.066
669.	0.074
769.	0.101
814.	0.115
CURVE 116*	
λ = 4.5	
472.	0.064
546.	0.059
578.	0.072
669.	0.076
769.	0.116
814.	0.118
CURVE 117*	
λ = 5.0	
472.	0.069
546.	0.067
578.	0.072
669.	0.077
769.	0.103
814.	0.120
CURVE 118*	
λ = 5.5	
472.	0.060
546.	0.061
578.	0.066
669.	0.066
769.	0.099
814.	0.108
CURVE 119*	
λ = 6.0	
472.	0.038
546.	0.039
578.	0.048
669.	0.048
769.	0.082
814.	0.090
CURVE 120*	
λ = 6.5	
472.	0.005
546.	0.017
578.	0.037
669.	0.039
769.	0.075
814.	0.093
CURVE 121*	
λ = 7.0	
546.	0.015
578.	0.029
669.	0.035
769.	0.067
814.	0.097
CURVE 122*	
λ = 7.5	
546.	0.012
578.	0.023
669.	0.030
769.	0.069
814.	0.085
CURVE 123*	
λ = 8.0	
578.	0.009
669.	0.020
769.	0.063
814.	0.061
CURVE 124*	
λ = 8.5	
578.	0.005
669.	0.019
769.	0.055
814.	0.071
CURVE 125*	
λ = 9.0	
669.	0.020
769.	0.068
814.	0.076
CURVE 126*	
λ = 9.5	
669.	0.012
769.	0.069
814.	0.078
CURVE 127*	
λ = 10.0	
769.	0.075
814.	0.080
CURVE 128*	
λ = 10.5	
769.	0.075
814.	0.079
CURVE 129*	
λ = 11.0	
769.	0.075
814.	0.078
CURVE 130*	
λ = 11.5	
769.	0.076
814.	0.069
CURVE 131*	
λ = 12.0	
769.	0.054
814.	0.054
CURVE 132*	
λ = 12.5	
769.	0.061
814.	0.055
CURVE 133*	
λ = 13.0	
769.	0.054
814.	0.055
CURVE 134*	
λ = 13.5	
769.	0.041
814.	0.043
CURVE 135*	
λ = 14.0	
769.	0.019
814.	0.023
CURVE 136*	
λ = 2.0	
603.	0.079
681.	0.067
731.	0.084
768.	0.087
808.	0.100
CURVE 137*	
λ = 2.5	
568.	0.031
603.	0.069
681.	0.056
731.	0.077
768.	0.080
808.	0.090
CURVE 138	
λ = 3.0	
470.	0.020
568.	0.042

* NOT SHOWN IN FIGURE.

TABLE 20-4. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM (TEMPERATURE DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

T	ε
CURVE 138 (CONT.)*	
603.	0.062
681.	0.062
731.	0.070
768.	0.073
808.	0.083
CURVE 139*	
λ = 3.5	
470.	0.031
568.	0.045
603.	0.061
681.	0.061
731.	0.069
768.	0.074
808.	0.086
CURVE 140*	
λ = 4.0	
470.	0.025
568.	0.044
603.	0.059
681.	0.061
731.	0.067
768.	0.073
808.	0.081
CURVE 141*	
λ = 4.5	
470.	0.022
568.	0.043
603.	0.057
681.	0.062
731.	0.063
768.	0.074
808.	0.080

T	ε
CURVE 142*	
λ = 5.0	
470.	0.018
568.	0.043
603.	0.054
681.	0.061
731.	0.067
768.	0.073
808.	0.080
CURVE 143*	
λ = 5.5	
470.	0.002
568.	0.034
603.	0.043
681.	0.060
731.	0.064
768.	0.073
808.	0.077
CURVE 144*	
λ = 6.0	
568.	0.038
603.	0.040
681.	0.055
731.	0.062
768.	0.070
808.	0.076
CURVE 145*	
λ = 6.5	
568.	0.012
603.	0.027
681.	0.051
731.	0.056
768.	0.067
808.	0.077

T	ε
CURVE 146*	
λ = 7.0	
568.	0.010
603.	0.024
681.	0.047
731.	0.055
768.	0.066
808.	0.075
CURVE 147*	
λ = 7.5	
568.	0.008
603.	0.017
681.	0.046
731.	0.053
768.	0.066
808.	0.073
CURVE 148*	
λ = 8.0	
603.	0.012
681.	0.044
731.	0.053
768.	0.066
808.	0.074
CURVE 149*	
λ = 8.5	
603.	0.006
681.	0.042
731.	0.052
768.	0.067
808.	0.074
CURVE 150*	
λ = 9.0	
681.	0.033

T	ε
CURVE 150 (CONT.)*	
731.	0.043
768.	0.060
808.	0.070
CURVE 151*	
λ = 9.5	
681.	0.033
731.	0.035
768.	0.056
CURVE 152*	
λ = 10.0	
681.	0.030
731.	0.032
768.	0.052
CURVE 153*	
λ = 10.5	
681.	0.016
768.	0.049
CURVE 154*	
λ = 11.0	
681.	0.014
768.	0.048
CURVE 155*	
λ = 11.5	
681.	0.010
768.	0.046
CURVE 156*	
λ = 2.0	
623.	0.165

T	ε
CURVE 156 (CONT.)*	
644.	0.113
724.	0.130
733.	0.190
883.	0.177
CURVE 157*	
λ = 2.5	
491.	0.102
513.	0.085
623.	0.120
644.	0.094
724.	0.111
733.	0.150
883.	0.147
CURVE 158	
λ = 3.0	
491.	0.082
513.	0.095
623.	0.105
644.	0.093
724.	0.100
733.	0.129
883.	0.125
CURVE 159*	
λ = 3.5	
491.	0.040
513.	0.052
623.	0.095
644.	0.092
724.	0.095
733.	0.120
883.	0.117

T	ε
CURVE 160*	
λ = 4.0	
491.	0.007
513.	0.037
623.	0.087
644.	0.087
724.	0.091
733.	0.114
883.	0.113
CURVE 161*	
λ = 4.5	
513.	0.024
623.	0.084
644.	0.086
724.	0.094
733.	0.115
883.	0.119
CURVE 162*	
λ = 5.0	
513.	0.036
623.	0.072
644.	0.085
724.	0.088
733.	0.110
883.	0.110
CURVE 163*	
λ = 5.5	
623.	0.046
644.	0.065
724.	0.073
733.	0.100
883.	0.113

* NOT SHOWN IN FIGURE.

TABLE 20-4. EXPERIMENTAL NORMAL SPECTRAL EMITTANCE OF ALUMINUM (TEMPERATURE DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ
CURVE 164*	
λ = 6.0	
623.	0.034
644.	0.058
724.	0.065
733.	0.093
883.	0.107
CURVE 165*	
λ = 6.5	
644.	0.026
883.	0.097
CURVE 166*	
λ = 7.0	
644.	0.028
883.	0.107
CURVE 167*	
λ = 7.5	
644.	0.020
883.	0.105
CURVE 168*	
λ = 8.0	
644.	0.016
883.	0.107

* NOT SHOWN IN FIGURE.

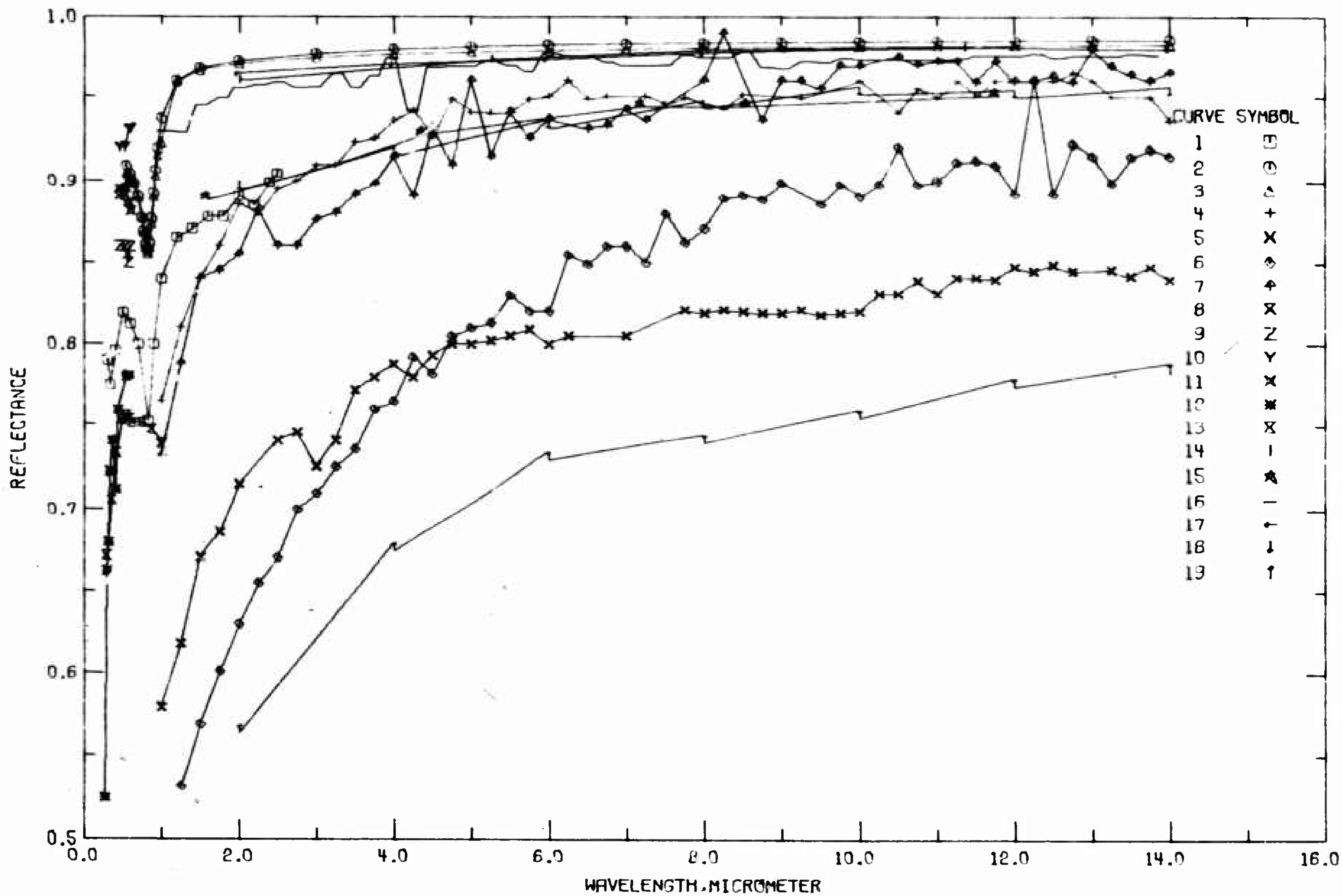


FIGURE 20-3. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM (WAVELENGTH DEPENDENCE).

TABLE 20-5. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF ALUMINUM (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T27253	Walin, D.R.	1960	0.30-2.50	298		Foil; cemented on fiberglas laminate; $\theta \sim 0°$, $\omega' = 2\pi$.
2	T27424	Bennett, H.E., Bennett, J.M., and Ashley, E.J.	1962	0.550-32	298		99.998 pure; Al film (0.065 to 0.11 μm thick), evaporated at 1×10^{-5} mm Hg, supersmooth fused quartz optical flats as substrate, no watermarks or other blemishes on the substrate surface, no shadows or streaks in the evaporated Al film; freshly prepared; measured in dry nitrogen; $\theta = 5°$, $\theta' = 5°$, reported error ±0.1%.
3	T27424	Bennett, H.E., et al.	1962	0.550-32	298		99.998 pure; Al film (0.065 to 0.11 μm thick), evaporated at 1×10^{-5} mm Hg, supersmooth fused quartz optical flats as substrate, no watermarks or other blemishes on the substrate surfaces, no shadows or streaks in the evaporated Al film; aged in air for several weeks; measured in dry nitrogen; $\theta = 5°$, $\theta' = 5°$, reported error ±0.1%.
4	T28940	Dunkle, R.V. and Gier, J.T.	1953	1.00-15.00	300		Foil; data extracted from smooth curve; converted from $R(2\pi, 5°)$; $\theta = 5°$, $\omega' = 2\pi$, reported error ±2.6%.
5	T28940	Dunkle, R.V. and Gier, J.T.	1953	1.00-15.00	300		Disc; polished, roughened (roughness approx. 1.27 μm); data extracted from smooth curve; converted from $R(2\pi, 5°)$; $\theta = 5°$, $\omega' = 2\pi$, reported error ±2.6%.
6	T28940	Dunkle, R.V. and Gier, J.T.	1953	1.00-15.00	300		Disc; commercial finish; data extracted from smooth curve; converted from $R(2\pi, 5°)$; $\theta = 5°$, $\omega' = 2\pi$, reported error ±4.3%.
7	T28940	Dunkle, R.V. and Gier, J.T.	1953	1.00-15.00	300		Disc; polished; data extracted from smooth curve; converted from $R(2\pi, 5°)$; $\theta = 5°$, $\omega' = 2\pi$, reported error ±2.7%.
8	T25806	Holland, L. and Williams, B.J.	1955	0.46-0.60	298		99 pure; vacuum deposited on glass; measured immediately after removed from vacuum chamber; calculated by authors from $\rho = 1 - \alpha$ using an incandescent tungsten lamp as source; $\theta = 10°$, $\omega' = 2\pi$, reported error ±0.5%.
9	T25806	Holland, L. and Williams, B.J.	1955	0.46-0.60	298		The above specimen and conditions except exposed to the atmosphere for 8 days.
10	T25806	Holland, L. and Williams, B.J.	1955	0.46-0.60	298		99.99 pure; vacuum deposited on glass; measured immediately after removed from vacuum chamber; calculated by authors from $\rho = 1 - \alpha$ using an incandescent tungsten lamp as source; $\theta = 10°$, $\omega' = 2\pi$.
11	T25806	Holland, L. and Williams, B.J.	1955	0.46-0.60	298		The above specimen and conditions except exposed to atmosphere for 8 days.
12	T7159	Wulff, J.	1934	0.235-0.578	298		Disc; cold worked, annealed, etch tested, polished, stored in a solution of NaOH + NaF, washed and dried; $\theta \sim 0°$, $\theta' \sim 0°$, reported error 2%.
13	T36320	Davies, J.M. and Zagieboylo, W.	1965	0.300-1.000	298		Sand blasted; $\theta \sim 0°$, $\omega' = 2\pi$.
14	T33512	Leigh, C.H.	1962	2.01-25.96	298		Polished; converted from $R(2\pi, 0°)$; $\theta \sim 0°$, $\omega' = 2\pi$.
15	T33512	Leigh, C.H.	1962	1.57-25.94	298		The above specimen and conditions except after particle impact.
16	T29648	Geir, J.T., Possner, L., Test, A.J., Dunkle, R.V., and Bevans, J.T.	1949	1.01-15.00	~298		Foil; data extracted from smooth curve; $\theta = 0°$, $\omega' = 2\pi$, reported error 5%.
17	T40413	Schocken, K. and Fountain, J.A.	1964	2.00-23.99	298		Polished; $\theta \sim 0°$, $\theta' \sim 0°$.

TABLE 20-5. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF ALUMINUM (Wavelength Dependence) (continued)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
18	T40413	Schocken, K. and Fountain, J.A.	1964	2.00-23.99	298		The above specimen and conditions except cratered with spherical particles (100 μm diameter) of Zircalloy at 1.5 km sec^{-1}; average crater diameter 123 μm; average crater depth 289 μm; Knoop hardness 22 (100 g load).
19	T40413	Schocken, K. and Fountain, J.A.	1964	2.00-22.00	298		Different sample, the above specimen and conditions except cratered with spherical particles (100 μm diameter) of tungsten at 7 km sec^{-1}; average crater diameter 54 μm; average crater depth 183 μm.

TABLE 23-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 1 T = 298.	
0.30	0.790
0.33	0.775
0.40	0.796
0.50	0.819
0.60	0.812
0.70	0.830
0.825	0.752
0.90	0.800
1.00	0.840
1.20	0.865
1.40	0.870
1.60	0.877
1.80	0.877
2.00	0.890
2.20	0.884
2.40	0.899
2.50	0.905
CURVE 2 T = 298.	
0.550	0.9394
0.600	0.9346
0.650	0.8969
0.700	0.8900
0.750	0.8761
0.775	0.8678
0.800	0.8604
0.825	0.8569
0.850	0.8622
0.875	0.8759
0.900	0.8920
0.925	0.9072
0.950	0.9192
1.000	0.9360
1.200	0.9596
1.500	0.9676
2.000	0.9718
3.000	0.9765
CURVE 2 (CONT.)	
4.	0.9795
5.	0.9812
6.	0.9823
7.	0.9831
8.	0.9837
9.	0.9841
10.	0.9845
11.	0.9849
12.	0.9854
13.	0.9857
14.	0.9861
16.	0.9868
18.	0.9873
20.	0.9878
22.	0.9883
24.	0.9887
26.	0.9890
28.	0.9893
30.	0.9896
32.	0.9898
CURVE 3 T = 298.	
0.550	0.9049
0.600	0.9021
0.650	0.8976
0.700	0.8886
0.750	0.8761
0.775	0.8678
0.800	0.8596
0.825	0.8555
0.850	0.8595
0.875	0.8730
0.900	0.8894
0.925	0.9030
0.950	0.9154
1.000	0.9224
1.200	0.9585
1.500	0.9658
CURVE 3 (CONT.)	
2.	0.9699
3.	0.9736
4.	0.9758
5.	0.9772
6.	0.9784
7.	0.9794
8.	0.9801
9.	0.9807
10.	0.9812
11.	0.9816
12.	0.9821
13.	0.9826
14.	0.9830
16.	0.9833
18.	0.9845
20.	0.9852
22.	0.9856
24.	0.9861
26.	0.9864
28.	0.9867
30.	0.9870
32.	0.9872
CURVE 4 T = 300.	
1.00	0.765
1.25	0.810
1.50	0.840
1.75	0.860
2.00	0.885
2.25	0.878
2.50	0.895
2.75	0.900
3.00	0.910
3.25	0.910
3.50	0.923
3.75	0.925
4.00	0.935
4.25	0.941
CURVE 4 (CONT.)	
4.50	0.925
4.75	0.948
5.00	0.940
5.25	0.939
5.50	0.940
5.75	0.948
6.00	0.950
6.25	0.960
6.50	0.948
6.75	0.950
7.25	0.950
7.50	0.945
7.75	0.949
8.00	0.945
8.25	0.942
8.50	0.951
9.25	0.949
10.00	0.960
10.50	0.940
10.75	0.955
11.00	0.949
11.25	0.960
11.50	0.951
11.75	0.960
12.50	0.960
12.75	0.965
13.00	0.960
13.25	0.950
13.75	0.950
14.00	0.935
14.25	0.955
14.75	0.936
15.00	0.925
CURVE 5 T = 300.	
1.00	0.579
1.25	0.618
1.50	0.670
CURVE 5 (CONT.)	
1.75	0.685
2.00	0.715
2.50	0.740
2.75	0.745
3.00	0.725
3.25	0.740
3.50	0.772
3.75	0.780
4.00	0.786
4.25	0.780
4.50	0.793
4.75	0.800
5.00	0.800
5.25	0.802
5.50	0.805
5.75	0.809
6.00	0.800
6.25	0.805
7.00	0.805
7.75	0.821
8.00	0.819
8.25	0.821
8.50	0.820
8.75	0.819
9.00	0.819
9.25	0.821
9.50	0.813
9.75	0.819
10.00	0.820
10.25	0.831
10.50	0.831
10.75	0.839
11.00	0.831
11.25	0.841
11.50	0.841
11.75	0.840
12.00	0.848
12.25	0.845
12.50	0.849
12.75	0.845
CURVE 5 (CONT.)	
13.25	0.846
13.50	0.842
13.75	0.848
14.00	0.840
14.25	0.841
14.50	0.843
14.75	0.855
15.00	0.840
CURVE 6 T = 300.	
1.00	0.470
1.25	0.530
1.50	0.569
1.75	0.601
2.00	0.630
2.25	0.655
2.50	0.670
2.75	0.700
3.00	0.710
3.25	0.725
3.50	0.735
3.75	0.760
4.00	0.765
4.25	0.792
4.50	0.762
4.75	0.805
5.00	0.810
5.25	0.813
5.50	0.830
5.75	0.820
6.00	0.820
6.25	0.855
6.50	0.849
6.75	0.860
7.00	0.860
7.25	0.850
7.50	0.879
7.75	0.862

TABLE 20-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 6 (CONT.)	
8.00	0.870
8.25	0.889
8.50	0.891
8.75	0.888
9.00	0.899
9.50	0.885
9.75	0.898
10.00	0.890
10.25	0.898
10.50	0.920
10.75	0.898
11.00	0.900
11.25	0.912
11.50	0.913
11.75	0.910
12.00	0.892
12.25	0.900
12.50	0.892
12.75	0.922
13.00	0.915
13.25	0.899
13.50	0.915
13.75	0.919
14.00	0.915
14.25	0.900
14.50	0.895
14.75	0.891
15.00	0.915
CURVE 7	
T = 300.	
1.00	0.731
1.25	0.788
1.50	0.840
1.75	0.845
2.00	0.855
2.25	0.861
2.50	0.865
2.75	0.860
CURVE 7 (CONT.)	
3.00	0.875
3.25	0.879
3.50	0.891
3.75	0.895
4.00	0.915
4.25	0.890
4.50	0.931
4.75	0.910
5.00	0.960
5.25	0.915
5.50	0.940
5.75	0.925
6.00	0.935
6.50	0.930
6.75	0.932
7.00	0.942
7.25	0.935
8.00	0.960
8.25	0.990
8.75	0.935
9.00	0.960
9.25	0.960
9.50	0.955
9.75	0.959
10.00	0.959
10.50	0.975
10.75	0.970
11.00	0.972
11.25	0.972
11.50	0.959
11.75	0.972
12.00	0.960
12.25	0.960
12.50	0.963
12.75	0.959
13.00	0.960
13.25	0.969
13.50	0.964
13.75	0.960
14.00	0.965
CURVE 7 (CONT.)	
14.25	0.951
14.50	0.969
14.75	0.955
15.00	0.972
CURVE 8	
T = 298.	
0.46	0.89
0.53	0.89
0.57	0.90
0.60	0.90
CURVE 9	
T = 298.	
0.46	0.86
0.53	0.86
0.57	0.85
0.60	0.86
CURVE 10	
T = 298.	
0.46	0.92
0.53	0.92
0.57	0.93
0.60	0.93
CURVE 11	
T = 298.	
0.46	0.895
0.53	0.895
0.57	0.885
0.60	0.885
CURVE 12	
T = 298.	
0.235	0.413
0.254	0.482
0.265	0.523
0.293	0.662
0.312	0.679
0.334	0.722
0.366	0.740
0.406	0.712
0.435	0.759
0.546	0.780
0.578	0.781
CURVE 13	
T = 298.	
0.300	0.671
0.357	0.706
0.419	0.733
0.488	0.753
0.533	0.755
0.579	0.754
0.627	0.751
0.752	0.751
0.871	0.747
1.000	0.738
CURVE 14	
T = 298.	
2.01	0.960
5.27	0.973
7.94	0.979
11.36	0.981
14.07	0.982
19.27	0.982
25.96	0.984
CURVE 15	
T = 298.	
1.57	0.890
4.34	0.929
7.17	0.940
8.53	0.946
11.73	0.953
14.46	0.954
17.38	0.961
19.33	0.961
22.54	0.957
25.94	0.952
CURVE 16	
T = 293.	
1.01	0.929
1.26	0.928
1.50	0.944
1.79	0.949
1.98	0.955
2.25	0.957
2.50	0.959
2.75	0.955
2.93	0.956
3.27	0.964
3.50	0.955
3.75	0.963
3.96	0.974
4.24	0.940
4.48	0.958
4.76	0.969
4.98	0.969
5.24	0.972
5.50	0.969
5.73	0.965
5.96	0.977
6.25	0.975
6.49	0.975
6.74	0.971
6.98	0.969
CURVE 16 (CONT.)	
7.25	0.969
7.51	0.970
7.76	0.975
7.98	0.974
8.26	0.974
8.53	0.978
8.76	0.968
9.00	0.967
9.29	0.972
9.55	0.971
9.79	0.974
10.01	0.973
10.27	0.973
10.53	0.973
10.77	0.973
11.04	0.973
11.30	0.974
11.52	0.976
11.78	0.975
12.02	0.976
12.27	0.977
12.51	0.974
12.79	0.976
13.01	0.976
13.26	0.978
13.50	0.977
13.79	0.976
14.01	0.976
14.28	0.977
14.53	0.973
14.75	0.966
15.00	0.971
CURVE 17	
T = 298.	
2.00	0.964
4.00	0.970
5.99	0.973
8.00	0.977

TABLE 20-6. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF ALUMINUM (WAVELENGTH DEPENDENCE) (CONTINUED)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
CURVE 17 (CONT.)	
10.00	0.980
12.00	0.981
14.00	0.980
16.00	0.980
18.00	0.980
20.00	0.979
22.00	0.979
23.99	0.973
CURVE 18	
T = 298.	
2.00	0.897
4.00	0.918
5.99	0.933
8.00	0.945
10.00	0.954
12.00	0.952
14.00	0.954
16.00	0.955
18.00	0.953
20.00	0.955
22.00	0.946
23.99	0.945
CURVE 19	
T = 298.	
2.00	0.566
4.00	0.576
5.99	0.731
8.00	0.741
10.00	0.757
12.00	0.777
14.00	0.786
16.00	0.789
18.00	0.793
20.00	0.792
22.00	0.792

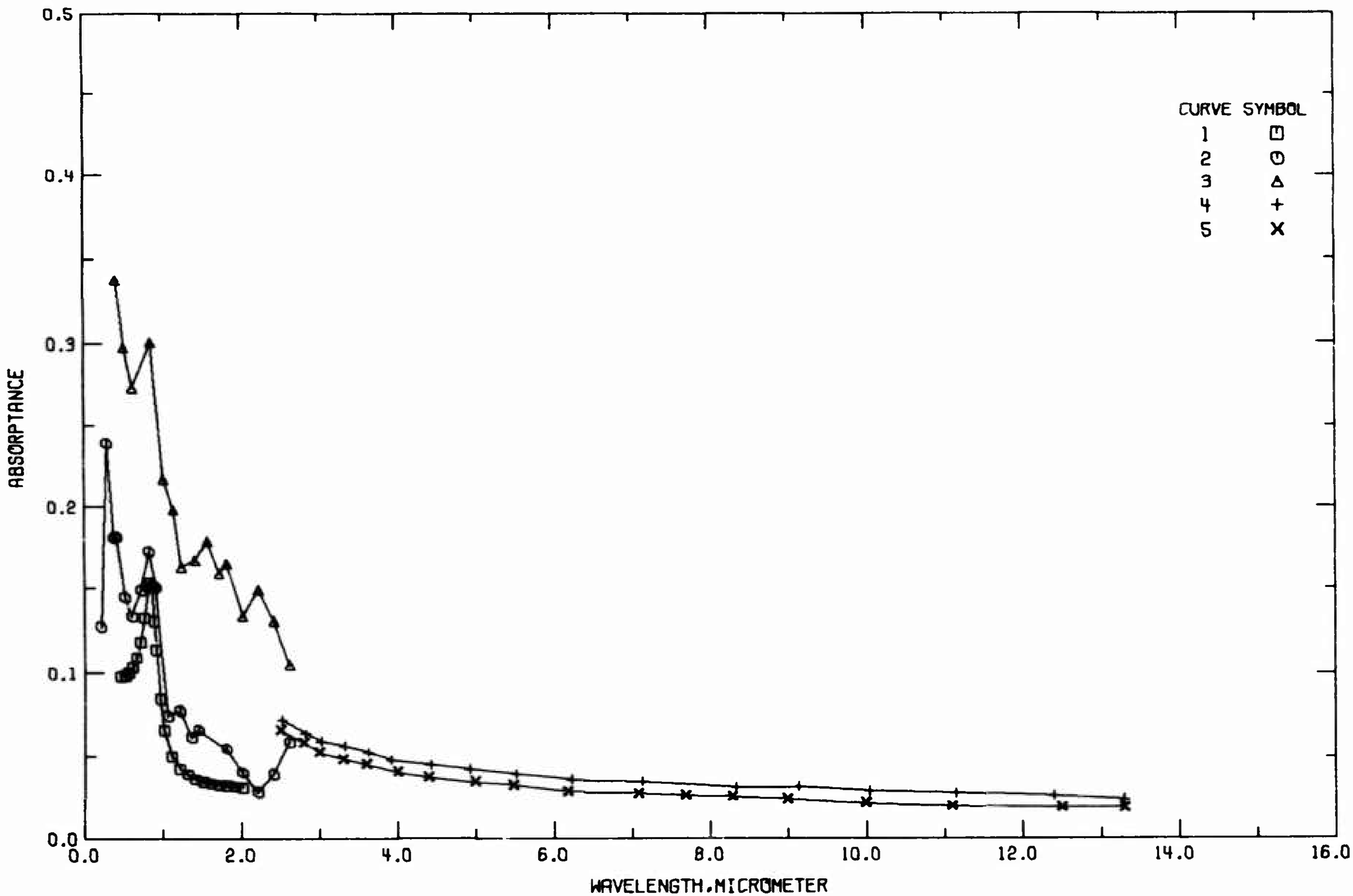


FIGURE 20-4. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM (WAVELENGTH DEPENDENCE).

TABLE 20-7. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	T34454	Brandenberg, W.M., Clausen, O.W., and McKeown, D.	1966	0.45-2.00	298		Evaporated film; evaporation rate 300 Å sec^{-1} at 2 x 10^{-5} mm Hg; measured in vacuum; aged 8 days before measurement; $\theta \sim 10°$, reported error ±1.4%.
2	T32388	Byrne, R.F. and Mancinelli, L.N.	1954	0.204-2.600	~298		Data extracted from smooth curve; $\theta \sim 0°$.
3	T32388	Byrne, R.F. and Mancinelli, L.N.	1954	0.402-2.600	~298		Polished; data extracted from smooth curve; $\theta \sim 0°$.
4	A00003	Harmon, N.F. (editor)	1974	2.5-20.0	573		Bulk sample; mechanically polished.
5	A00003	Harmon, N.F. (editor)	1974	2.5-20.0	293		The above specimen except at 293 K.

TABLE 20-8. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α
CURVE 1	
T = 298.	
0.45	0.0982
0.50	0.0987
0.55	0.1001
0.60	0.1037
0.65	0.1096
0.70	0.1189
0.75	0.1331
0.80	0.1511
0.825	0.1533
0.850	0.1501
0.875	0.1311
0.90	0.1142
0.95	0.0846
1.00	0.0653
1.10	0.0498
1.20	0.0420
1.30	0.0387
1.40	0.0357
1.50	0.0341
1.60	0.0331
1.70	0.0322
1.80	0.0319
1.90	0.0313
2.00	0.0338
CURVE 2	
T = 298.	
0.204	0.128
0.231	0.239
0.367	0.181
0.401	0.182
0.506	0.145
0.597	0.134
0.709	0.149
0.815	0.173
0.895	0.151
1.048	0.075
1.200	0.076

λ	α
CURVE 2 (CONT.)	
1.352	0.062
1.449	0.067
1.798	0.055
2.000	0.040
2.200	0.028
2.400	0.039
2.600	0.059
CURVE 3	
T = 298.	
0.402	0.338
0.498	0.298
0.607	0.273
0.841	0.301
0.997	0.217
1.119	0.198
1.220	0.163
1.397	0.167
1.553	0.179
1.704	0.159
1.800	0.165
2.000	0.134
2.200	0.149
2.400	0.131
2.600	0.105
CURVE 4	
T = 573.	
2.5	0.0721
2.8	0.0642
3.0	0.0593
3.3	0.0562
3.6	0.0522
3.9	0.0474
4.4	0.0446
4.9	0.0419
5.5	0.0359
6.2	0.0354

λ	α
CURVE 4 (CONT.)	
7.1	0.0344
8.3	0.0307
9.1	0.0314
10.0	0.0285
11.1	0.0272
12.4	0.0253
13.3	0.0232
14.2	0.0239
15.3	0.0234
16.6	0.0215
17.3	0.0226
19.0	0.0221
19.9	0.0212
CURVE 5	
T = 293.	
2.5	0.0667
2.8	0.0589
3.0	0.0527
3.3	0.0486
3.6	0.0453
4.0	0.0405
4.4	0.0375
5.0	0.0345
5.5	0.0325
6.2	0.0285
7.1	0.0277
7.7	0.0265
8.3	0.0257
9.0	0.0243
10.0	0.0216
11.1	0.0200
12.5	0.0187
13.3	0.0186
14.2	0.0178
15.3	0.0175
16.6	0.0176
17.3	0.0166
19.0	0.0159

λ	α
CURVE 5 (CONT.)	
19.9	0.0157

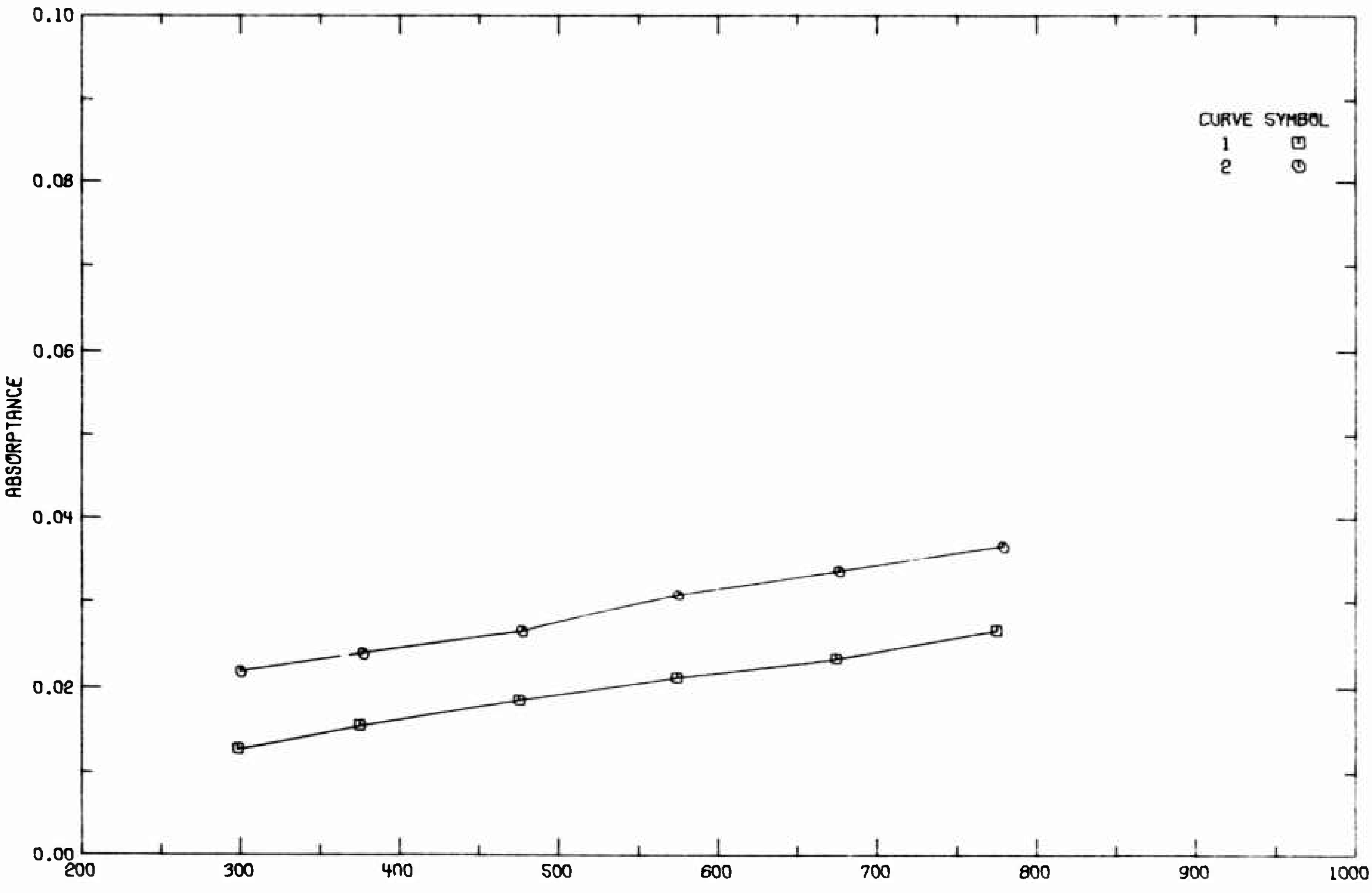


FIGURE 20-5. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM (TEMPERATURE DEPENDENCE).

TABLE 20-9. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM (Temperature Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00003	Harmon, N.F. (editor)	1974	5.0	300-779		Film; fast-evaporated; absorptance obtained for wavelength 5.0 μm at various temperatures.
2	A00003	Harmon, N.F. (editor)	1974	10.0	298-775		The above specimen except wavelength 10.0 μm.

TABLE 20-10. EXPERIMENTAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINUM (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSCRPTANCE, α]

T	α
CURVE 1 λ = 10.0	
295.	0.0129
375.	0.0155
475.	0.0185
574.	0.0213
674.	0.0234
775.	0.0265
CURVE 2 λ = 5.0	
300.	0.0219
377.	0.0239
477.	0.0264
575.	0.0308
676.	0.0337
779.	0.0366

To isolate the individual surface characteristics is a difficult task. For most materials it is not practical to alter one characteristic without causing an influence on another. The control of the many variables required to study surface characterization in a logical manner is a complex problem. As a result only the simplest of surface profiles or compositional effects have been studied or are understood. One of the most important influences on the radiative properties of metals arises from surface roughness.

Because of the difficulties mentioned above, data analysis and evaluation is not a straight forward task; some logical but not exact means should be used in the generation of the most probable values for the properties of our interest. Although the radiative properties could be strongly dependent upon the process of applying the metallized thin films, we considered them as mechanically polished surface as a first approximation and decided to use the classical model of Hagen and Rubens with some modification in the interpretation of the selected emittance data for mechanically polished surfaces. Details of such modification are discussed in Section 2 and Eq. (2.5-5) is the resulted expression.

Reliable and accurate available data on the normal spectral emittance of mechanically polished aluminum surface were obtained by converting the data sets, curves 4 and 5 of Figure 20-4, from absorptance to emittance using Kirchhoff's law. Data for curves 4 and 5 were measured at temperatures of 573 K and 293 K respectively. By a least squares calculation the following equation was found to fit the selected data with uncertainties of less than $\pm 10\%$ for wavelength range 2.5 to 20 μm.

$$\epsilon(0,\lambda) = 0.0007 + 0.0644\left[\frac{1 + 0.00429\,(T-293)}{\lambda - 2.279}\right]^{1/2} - 0.0206\left[\frac{1 + 0.00429\,(T-293)}{\lambda - 2.279}\right] + 0.00234\left[\frac{1 + 0.00429\,(T-293)}{\lambda - 2.279}\right]^{3/2}, \tag{4.20-1}$$

$$\alpha(0,\lambda) = \epsilon(0,\lambda), \tag{4.20-2}$$

and

$$\rho(0,2\pi,\lambda) = 1 - \alpha(0,\lambda), \tag{4.20-3}$$

where λ is in units of μm and T in K. These three equations are used to generate the most probable values on the normal spectral radiative properties for the aluminized grafoil.

a. Normal Spectral Emittance (Wavelength Dependence)

Normal spectral emittance of aluminized grafoil is calculated from Eq. (4.20-1) and listed in Table 20-11 and plotted in Figure 20-6. The values generated are considered as provisional (about ± 25% uncertainty) since they are estimated based on the aluminum data. Provisional values are presented at five temperatures, 293, 450, 600, 750, and 850 K. Note that the provisional values are for the mechanically polished surface only. Values of true surfaces are expected to deviate from those listed. However, the tabulated values are believed to be reasonable for those surfaces of roughness less than 0.5 μm.

TABLE 23-11. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ALUMINIZED GRAFOIL (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
MECHANICALLY POLISHED T = 293		MECHANICALLY POLISHED T = 450		MECHANICALLY POLISHED T = 600		MECHANICALLY POLISHED T = 750		MECHANICALLY POLISHED T = 853	
2.5	0.067	2.5	0.071	2.5	0.073	2.5	0.075	2.5	0.078
2.8	0.057	2.8	0.063	2.8	0.067	2.8	0.069	2.8	0.070
3.0	0.052	3.0	0.059	3.0	0.063	3.0	0.066	3.0	0.067
3.5	0.044	3.5	0.052	3.5	0.056	3.5	0.060	3.5	0.062
3.8	0.041	3.8	0.048	3.8	0.053	3.8	0.057	3.8	0.059
4.0	0.039	4.0	0.045	4.0	0.051	4.0	0.055	4.0	0.057
4.5	0.035	4.5	0.043	4.5	0.047	4.5	0.051	4.5	0.053
5.0	0.033	5.0	0.040	5.0	0.044	5.0	0.048	5.0	0.050
5.5	0.031	5.5	0.037	5.5	0.042	5.5	0.046	5.5	0.048
6.0	0.029	6.0	0.035	6.0	0.040	6.0	0.043	6.0	0.045
6.5	0.027	6.5	0.034	6.5	0.038	6.5	0.042	6.5	0.044
7.0	0.026	7.0	0.032	7.0	0.037	7.0	0.040	7.0	0.042
7.5	0.025	7.5	0.031	7.5	0.035	7.5	0.039	7.5	0.040
8.0	0.024	8.0	0.030	8.0	0.034	8.0	0.037	8.0	0.039
8.5	0.023	8.5	0.029	8.5	0.033	8.5	0.036	8.5	0.038
9.0	0.023	9.0	0.028	9.0	0.032	9.0	0.035	9.0	0.037
9.5	0.022	9.5	0.027	9.5	0.031	9.5	0.034	9.5	0.036
10.0	0.021	10.0	0.026	10.0	0.030	10.0	0.033	10.0	0.035
10.5	0.021	10.5	0.026	10.5	0.029	10.5	0.032	10.5	0.034
11.0	0.020	11.0	0.025	11.0	0.029	11.0	0.032	11.0	0.033
11.5	0.020	11.5	0.025	11.5	0.028	11.5	0.031	11.5	0.033
12.0	0.019	12.0	0.024	12.0	0.028	12.0	0.030	12.0	0.032
12.5	0.019	12.5	0.024	12.5	0.027	12.5	0.030	12.5	0.031
13.0	0.019	13.0	0.023	13.0	0.026	13.0	0.029	13.0	0.031
13.5	0.018	13.5	0.023	13.5	0.026	13.5	0.029	13.5	0.030
14.0	0.018	14.0	0.022	14.0	0.025	14.0	0.028	14.0	0.030
14.5	0.017	14.5	0.022	14.5	0.025	14.5	0.028	14.5	0.029
15.0	0.017	15.0	0.021	15.0	0.025	15.0	0.027	15.0	0.029

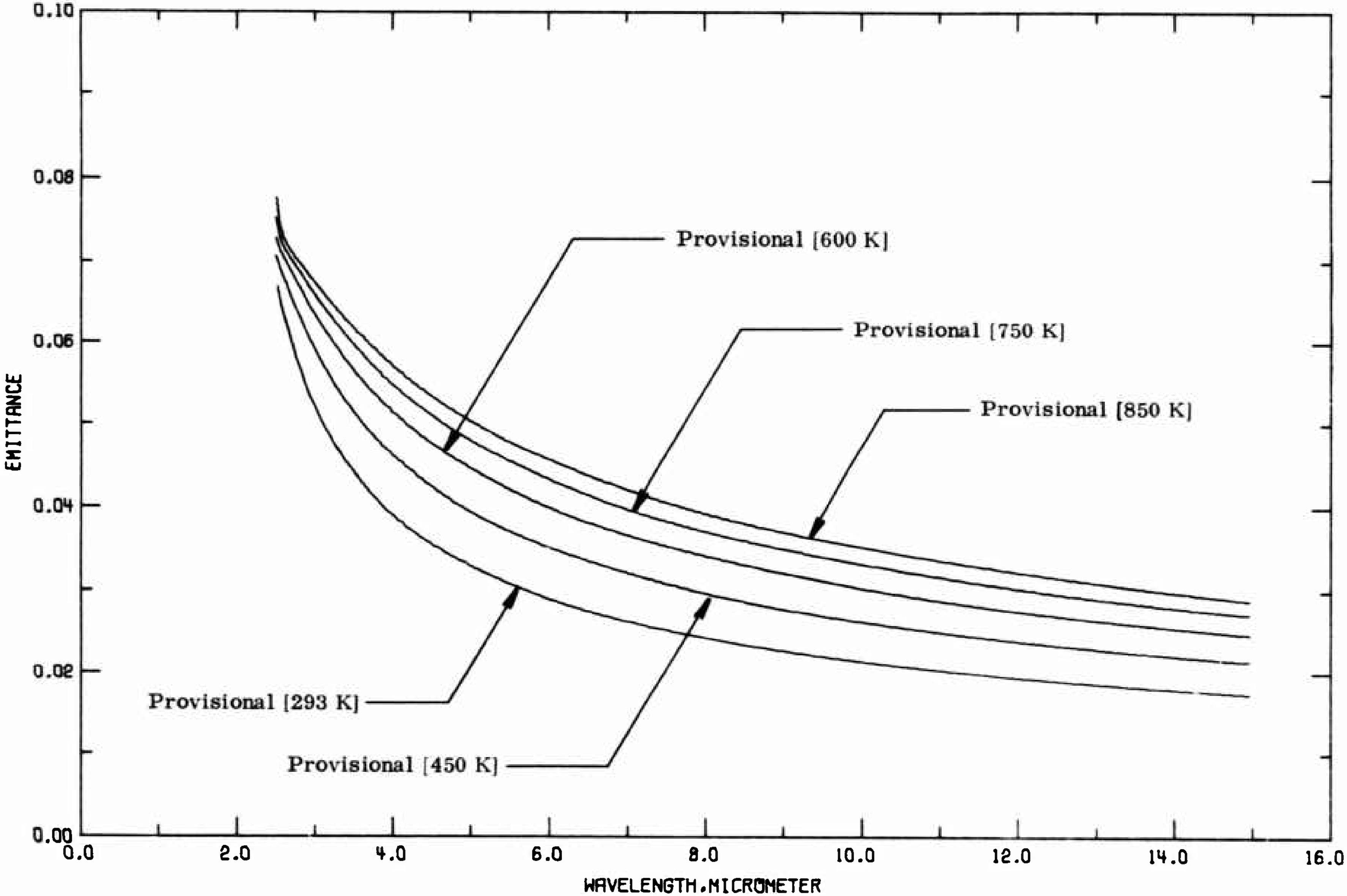


FIGURE 20-6. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ALUMINIZED GRAFOIL (WAVELENGTH DEPENDENCE).

b. Normal Spectral Emittance (Temperature Dependence)

The normal spectral emittance as a function of temperature is given in Table 20-12 and Figure 20-7. The generated values are considered as provisional (uncertainty ±25%). The plot clearly shows that emittance for a given wavelength does not vary appreciably for a wide temperature range. Note that the melting point of aluminum at about 930 K is not far from the ending point (about 880 K) of each curve. It seems that the curves can be extrapolated to or beyond the melting point. However, there is no definite evidence to support this attempt.

TABLE 26-12. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ALUMINIZED GRAFOIL (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

T	ε	T	ε	T	ε	T	ε
MECHANICALLY POLISHED λ = 2.8		MECHANICALLY POLISHED λ = 3.8		MECHANICALLY POLISHED λ = 5.0		MECHANICALLY POLISHED λ = 10.6	
250.0	0.054	250.0	0.038	250.0	0.030	250.0	0.019
293.0	0.057	293.0	0.041	293.0	0.033	293.0	0.021
300.0	0.057	300.0	0.041	300.0	0.033	300.0	0.021
350.0	0.060	350.0	0.044	350.0	0.036	350.0	0.023
400.0	0.062	400.0	0.046	400.0	0.038	400.0	0.024
450.0	0.063	450.0	0.048	450.0	0.040	450.0	0.026
500.0	0.065	500.0	0.050	500.0	0.041	500.0	0.027
550.0	0.066	550.0	0.052	550.0	0.043	550.0	0.028
600.0	0.067	600.0	0.053	600.0	0.044	600.0	0.029
650.0	0.068	650.0	0.055	650.0	0.046	650.0	0.030
700.0	0.068	700.0	0.056	700.0	0.047	700.0	0.031
750.0	0.069	750.0	0.057	750.0	0.048	750.0	0.032
800.0	0.069	800.0	0.058	800.0	0.049	800.0	0.033
850.0	0.070	850.0	0.059	850.0	0.050	850.0	0.034
880.0	0.070	880.0	0.059	880.0	0.051	880.0	0.035

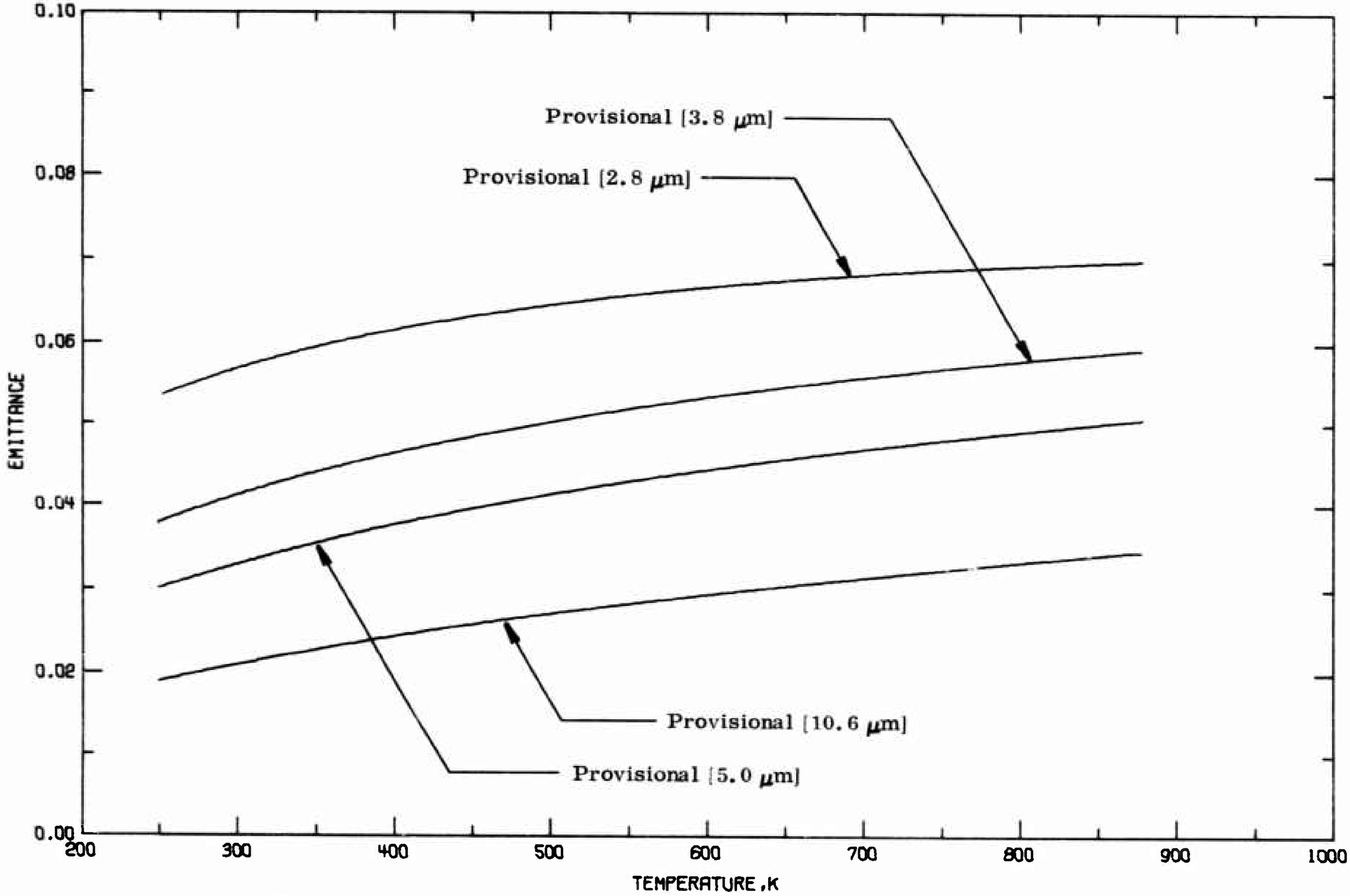


FIGURE 20-7. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF ALUMINIZED GRAFOIL (TEMPERATURE DEPENDENCE).

c. Normal Spectral Reflectance (Wavelength Dependence)

As given in Table 20-13 and plotted in Figure 20-8 the normal spectral reflectance of aluminized grafoil is calculated by assuming that energy loss of the impinging radiation is entirely due to absorption. The result is remarkably good as one can see by comparing Figures 20-3 and 20-8. Since the data analysis is totally based on the available data of aluminum, allowance is given in the estimation of the predicted values. An estimated uncertainty of ± 20% is given to the calculated values so that the estimated values can be used for most of the true surfaces.

TABLE 20-13. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF ALUMINIZED GRAFOIL (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
MECHANICALLY POLISHED T = 233		MECHANICALLY POLISHED T = 450		MECHANICALLY POLISHED T = 600		MECHANICALLY POLISHED T = 750		MECHANICALLY POLISHED T = 850	
2.5	0.933	2.5	0.929	2.5	0.927	2.5	0.925	2.5	0.922
2.8	0.943	2.8	0.937	2.8	0.933	2.8	0.931	2.8	0.930
3.0	0.948	3.0	0.941	3.0	0.937	3.0	0.934	3.0	0.933
3.5	0.956	3.5	0.948	3.5	0.944	3.5	0.940	3.5	0.938
3.8	0.959	3.8	0.952	3.8	0.947	3.8	0.943	3.8	0.941
4.0	0.961	4.0	0.954	4.0	0.949	4.0	0.945	4.0	0.943
4.5	0.965	4.5	0.957	4.5	0.953	4.5	0.949	4.5	0.947
5.0	0.967	5.0	0.960	5.0	0.956	5.0	0.952	5.0	0.950
5.5	0.969	5.5	0.963	5.5	0.958	5.5	0.954	5.5	0.952
6.0	0.971	6.0	0.965	6.0	0.960	6.0	0.957	6.0	0.955
6.5	0.973	6.5	0.966	6.5	0.962	6.5	0.958	6.5	0.956
7.0	0.974	7.0	0.968	7.0	0.963	7.0	0.960	7.0	0.958
7.5	0.975	7.5	0.969	7.5	0.965	7.5	0.961	7.5	0.960
8.0	0.976	8.0	0.970	8.0	0.966	8.0	0.963	8.0	0.961
8.5	0.977	8.5	0.971	8.5	0.967	8.5	0.964	8.5	0.962
9.0	0.977	9.0	0.972	9.0	0.968	9.0	0.965	9.0	0.963
9.5	0.978	9.5	0.973	9.5	0.969	9.5	0.966	9.5	0.964
10.0	0.979	10.0	0.974	10.0	0.970	10.0	0.967	10.0	0.965
10.5	0.979	10.5	0.974	10.5	0.971	10.5	0.968	10.5	0.966
11.0	0.980	11.0	0.975	11.0	0.971	11.0	0.968	11.0	0.967
11.5	0.980	11.5	0.975	11.5	0.972	11.5	0.969	11.5	0.967
12.0	0.981	12.0	0.976	12.0	0.972	12.0	0.970	12.0	0.968
12.5	0.981	12.5	0.976	12.5	0.973	12.5	0.970	12.5	0.969
13.0	0.981	13.0	0.977	13.0	0.974	13.0	0.971	13.0	0.969
13.5	0.982	13.5	0.977	13.5	0.974	13.5	0.971	13.5	0.970
14.0	0.982	14.0	0.978	14.0	0.975	14.0	0.972	14.0	0.970
14.5	0.983	14.5	0.978	14.5	0.975	14.5	0.972	14.5	0.971
15.0	0.983	15.0	0.979	15.0	0.975	15.0	0.973	15.0	0.971

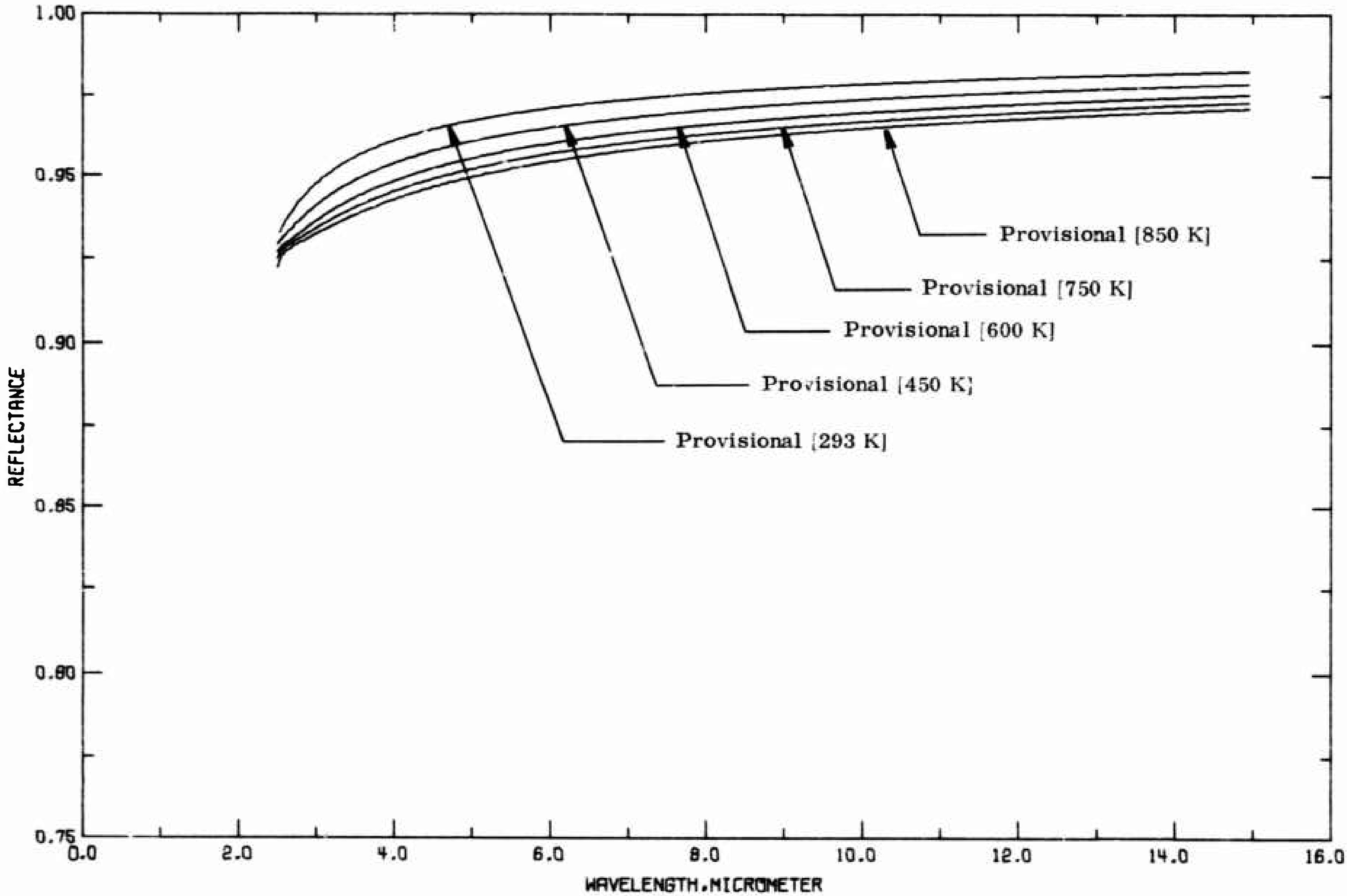


FIGURE 20-8. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF ALUMINIZED GRAFOIL (WAVELENGTH DEPENDENCE).

d. Normal Spectral Reflectance (Temperature Dependence)

In Table 20-14, the provisional values of the normal spectral reflectance are given with an estimated uncertainty of ± 20%. The variation of the property as a function of temperature is demonstrated in Figure 20-9. For a given wavelength, the normal spectral reflectance remains as a constant from room temperature up to near the melting point of the material. At higher temperatures our knowledge on this property is lacking. However, it seems that a linear extrapolation of the curve to and above the melting point can be used with uncertainty of no more than ± 35%.

TABLE 20-14. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF ALUMINIZED GRAFOIL (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

T	ρ	T	ρ	T	ρ	T	ρ
MECHANICALLY POLISHED λ = 2.8		MECHANICALLY POLISHED λ = 3.8		MECHANICALLY POLISHED λ = 5.0		MECHANICALLY POLISHED λ = 10.6	
250.0	0.946	250.0	0.962	250.0	0.970	250.0	0.981
293.0	0.943	293.0	0.959	293.0	0.967	293.0	0.979
300.0	0.943	300.0	0.959	300.0	0.967	300.0	0.978
350.0	0.940	350.0	0.956	350.0	0.964	350.0	0.977
400.0	0.938	400.0	0.954	400.0	0.962	400.0	0.976
450.0	0.937	450.0	0.952	450.0	0.960	450.0	0.974
500.0	0.935	500.0	0.950	500.0	0.959	500.0	0.973
550.0	0.934	550.0	0.948	550.0	0.957	550.0	0.972
600.0	0.933	600.0	0.947	600.0	0.956	600.0	0.971
650.0	0.932	650.0	0.945	650.0	0.954	650.0	0.970
700.0	0.932	700.0	0.944	700.0	0.953	700.0	0.969
750.0	0.931	750.0	0.943	750.0	0.952	750.0	0.968
800.0	0.931	800.0	0.942	800.0	0.951	800.0	0.967
850.0	0.930	850.0	0.941	850.0	0.950	850.0	0.966
880.0	0.930	880.0	0.941	880.0	0.949	830.0	0.965

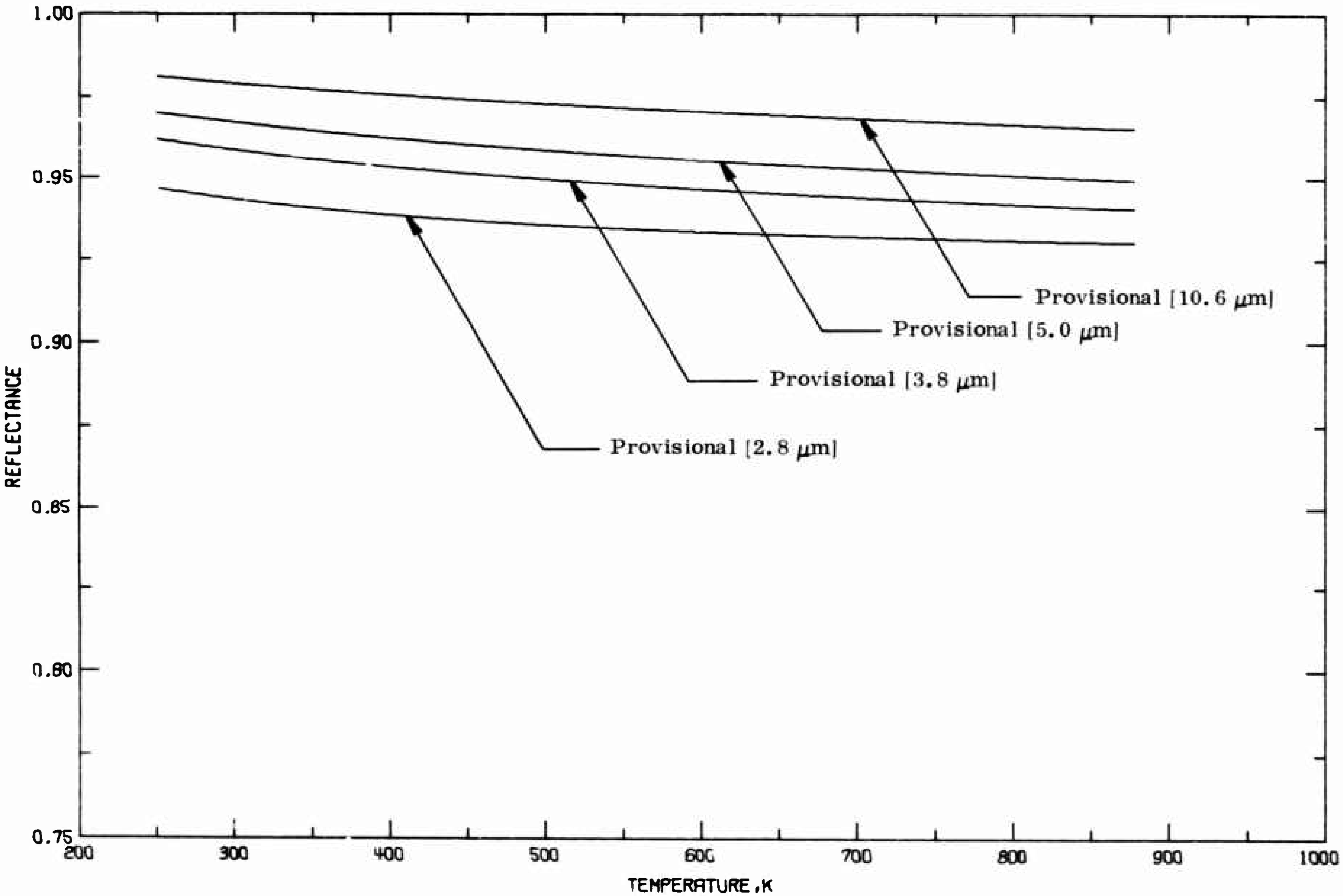


FIGURE 20-9. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF ALUMINIZED GRAFOIL (TEMPERATURE DEPENDENCE).

e. Normal Spectral Absorptance (Wavelength Dependence)

The normal spectral absorptance is obtained from reflectance according to the Kirchhoff's law, and is numerically equal to the emittance. The absorptance varies appreciably for wavelengths lower than 4.0 μm and remains practically unchanged for longer wavelengths. The generated provisional values with $\pm 25\%$ uncertainty are given in Table 20-15 and plotted in Figure 20-10.

TABLE 23-15. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINIZED GRAFOIL (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α	λ	α	λ	α
MECHANICALLY POLISHED T = 293		MECHANICALLY POLISHED T = 450		MECHANICALLY POLISHED T = 600		MECHANICALLY POLISHED T = 750		MECHANICALLY POLISHED T = 850	
2.5	0.067	2.5	0.071	2.5	0.073	2.5	0.075	2.5	0.076
2.8	0.057	2.8	0.063	2.8	0.067	2.8	0.069	2.8	0.070
3.0	0.052	3.0	0.059	3.0	0.063	3.0	0.066	3.0	0.067
3.5	0.044	3.5	0.052	3.5	0.056	3.5	0.060	3.5	0.062
3.8	0.041	3.8	0.048	3.8	0.053	3.8	0.057	3.8	0.059
4.0	0.039	4.0	0.046	4.0	0.051	4.0	0.055	4.0	0.057
4.5	0.035	4.5	0.043	4.5	0.047	4.5	0.051	4.5	0.053
5.0	0.033	5.0	0.040	5.0	0.044	5.0	0.048	5.0	0.050
5.5	0.031	5.5	0.037	5.5	0.042	5.5	0.046	5.5	0.048
6.0	0.029	6.0	0.035	6.0	0.040	6.0	0.043	6.0	0.045
6.5	0.027	6.5	0.034	6.5	0.038	6.5	0.042	6.5	0.044
7.0	0.026	7.0	0.032	7.0	0.037	7.0	0.040	7.0	0.042
7.5	0.025	7.5	0.031	7.5	0.035	7.5	0.039	7.5	0.040
8.0	0.024	8.0	0.030	8.0	0.034	8.0	0.037	8.0	0.039
8.5	0.023	8.5	0.029	8.5	0.033	8.5	0.036	8.5	0.038
9.0	0.023	9.0	0.028	9.0	0.032	9.0	0.035	9.0	0.037
9.5	0.022	9.5	0.027	9.5	0.031	9.5	0.034	9.5	0.036
10.0	0.021	10.0	0.026	10.0	0.030	10.0	0.033	10.0	0.035
10.5	0.021	10.5	0.026	10.5	0.029	10.5	0.032	10.5	0.034
11.0	0.020	11.0	0.025	11.0	0.029	11.0	0.032	11.0	0.033
11.5	0.020	11.5	0.025	11.5	0.028	11.5	0.031	11.5	0.033
12.0	0.019	12.0	0.024	12.0	0.028	12.0	0.030	12.0	0.032
12.5	0.019	12.5	0.024	12.5	0.027	12.5	0.030	12.5	0.031
13.0	0.019	13.0	0.023	13.0	0.026	13.0	0.029	13.0	0.031
13.5	0.018	13.5	0.023	13.5	0.026	13.5	0.029	13.5	0.030
14.0	0.018	14.0	0.022	14.0	0.025	14.0	0.028	14.0	0.030
14.5	0.017	14.5	0.022	14.5	0.025	14.5	0.028	14.5	0.029
15.0	0.017	15.0	0.021	15.0	0.025	15.0	0.027	15.0	0.029

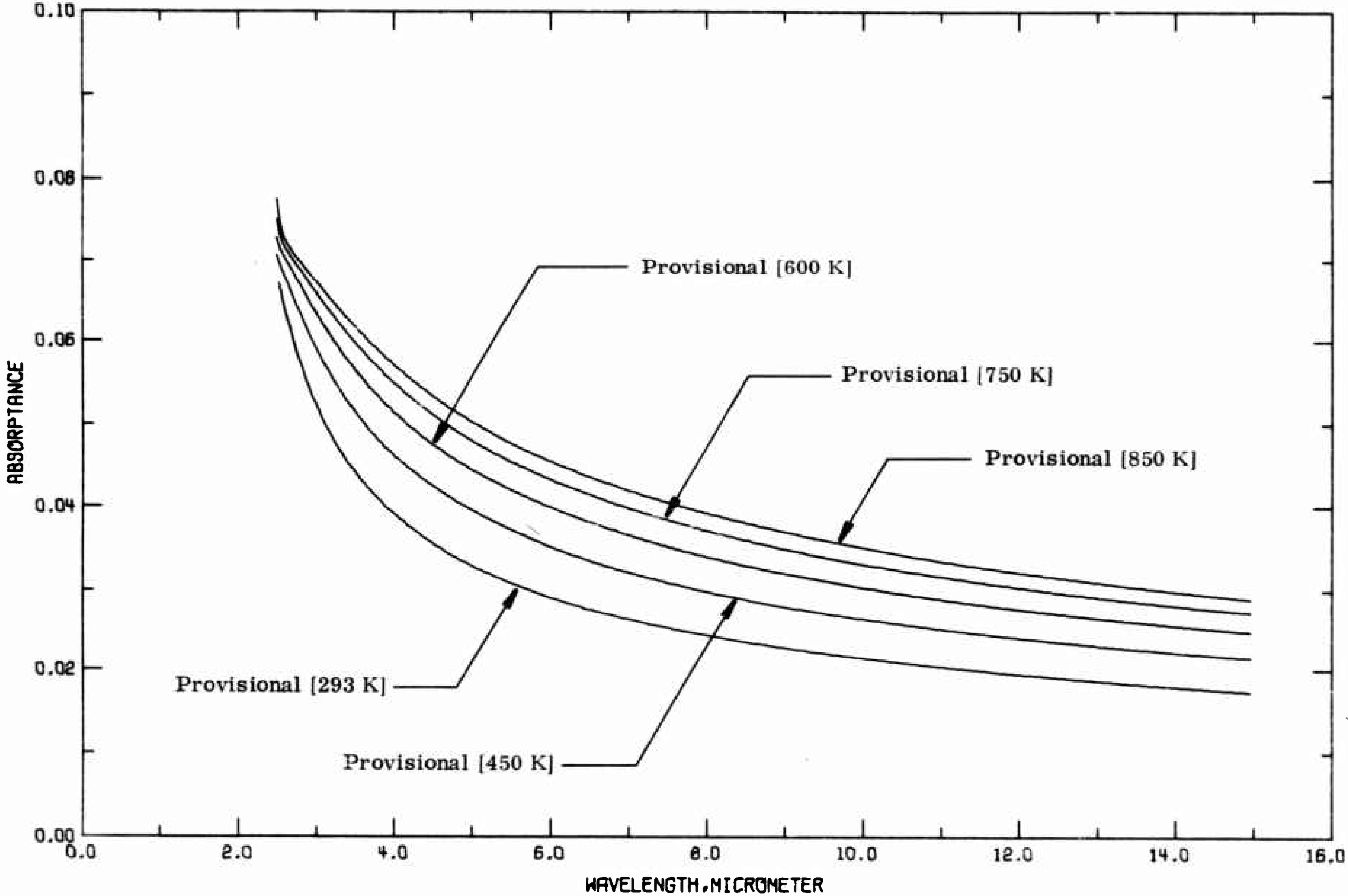


FIGURE 2G-10. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINIZED GRAFOIL (WAVELENGTH DEPENDENCE).

f. Normal Spectral Absorptance (Temperature Dependence)

The provisional values of the normal spectral absorptance of aluminized grafoil is given in Table 20-16 and plotted in Figure 20-11. They are numerically equal to the normal spectral emittance. Comparing our predicted curves for 5.0 μm and 10.0 μm with the available data in Figure 20-5, it appears that our predicted values are higher than experimental values. By a careful examination of the measurement information, one sees that the experimental points in Figure 20-5 are for thin films. The absorptance of bulk material is in general higher than that of thin film. An uncertainty of 25% is incooperated to the provisional values so that they can be used for most of the real surfaces.

TABLE 20-16. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINIZED GRAFOIL (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

T	α	T	α	T	α	T	α
MECHANICALLY POLISHED λ = 2.8		MECHANICALLY POLISHED λ = 3.8		MECHANICALLY POLISHED λ = 5.0		MECHANICALLY POLISHED λ = 10.6	
250.0	0.054	250.0	0.038	250.0	0.030	250.0	0.019
293.0	0.057	293.0	0.041	293.0	0.033	293.0	0.021
300.0	0.057	300.0	0.041	300.0	0.033	300.0	0.021
350.0	0.060	350.0	0.044	350.0	0.036	350.0	0.023
400.0	0.062	400.0	0.046	400.0	0.038	400.0	0.024
450.0	0.063	450.0	0.048	450.0	0.040	450.0	0.026
500.0	0.065	500.0	0.050	500.0	0.041	500.0	0.027
550.0	0.066	550.0	0.052	550.0	0.043	550.0	0.028
600.0	0.067	600.0	0.053	600.0	0.044	600.0	0.029
650.0	0.068	650.0	0.055	650.0	0.046	650.0	0.030
700.0	0.068	700.0	0.056	700.0	0.047	700.0	0.031
750.0	0.069	750.0	0.057	750.0	0.048	750.0	0.032
800.0	0.069	800.0	0.058	800.0	0.049	800.0	0.033
850.0	0.070	850.0	0.059	850.0	0.050	850.0	0.034
880.0	0.070	880.0	0.059	880.0	0.051	880.0	0.035

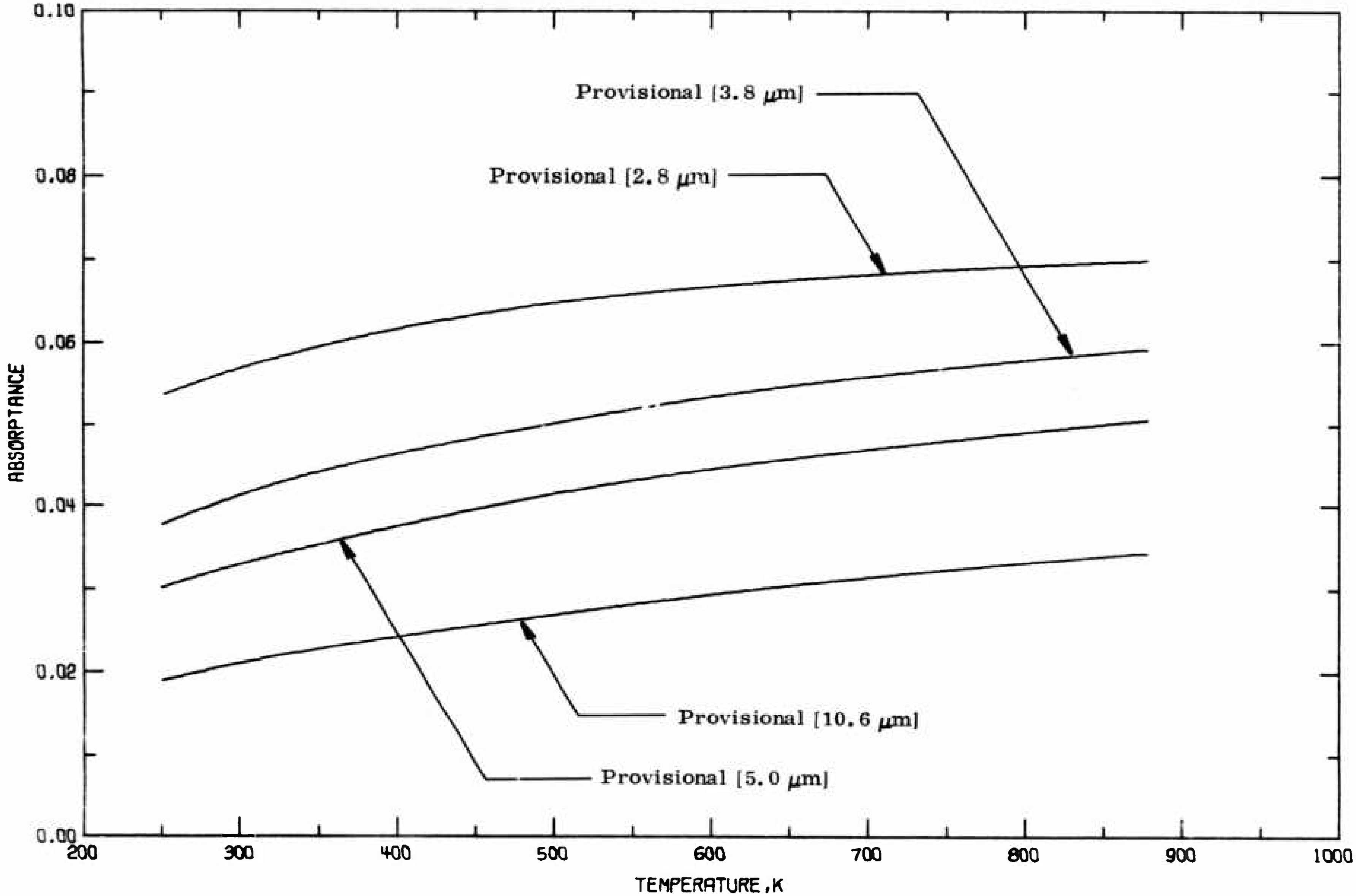


FIGURE 20-11. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF ALUMINIZED GRAFOIL (TEMPERATURE DEPENDENCE).

g. Transmittance

Although it is true that metals in the form of extremely thin films may be transparent for a wide wavelength range, they are opaque if the thickness is greater than several hundred angstroms. Consequently, composites with a metal layer are opaque to visible and infrared radiation because in general applications they are not used as extremely thin films. This leads to the conclusion that as an aircraft/spacecraft structural material, this composite is opaque and its transmittance is zero.

4.21. Boron Fiber Aluminum Matrix Composite

Boron fiber aluminum matrix composite is made in the form of sheet or tape. The sheets are made by diffusion bonding boron fibers between two sheets of aluminum or aluminum alloys. The tape is made by plasma spraying the 713 braze alloys. The tape is then diffusion or braze bonded into any desired configuration.

Boron filaments are formed by the vapor deposition of boron on a fine tungsten wire substrate within a reactor. Exposure of the tungsten substrate to the high temperature boron trichloride reactor environment results in a filament consisting of a boron sheath on a tungsten boride core. Boron fibers have higher tensile strength and modulus of elasticity than the graphite fibers commonly used in composite materials. Their melting point is higher than that of aluminum generally used in conjunction with them. The boron filaments are currently produced by two principal sources, Hamilton Standard and Avco. It might be noted that composites using Borsic filaments are also available commercially. These are boron filaments coated with silicon carbide in order to adapt boron filaments to high temperature usage in composite.

In the area of metal matrix, aluminum or aluminum alloys are currently commercially available.

The advantage of the boron fiber aluminum matrix composite is that along with its light weight it has a high temperature and heat resistance. Although the fiber material stands very high temperatures, its aluminum composite is not recommended for continuous service above 590 K, but the intermittent service to 645 K is possible. The products are available commercially in a wide range of laminate thickness including monolayer sheets in finished form. Virtually all of the actual hardware items built to date have been fabricated using standard fiber volume fractions of fifty percent.

The composite materials are fabricated primarily for aircraft constructions because of their advantages. Much of their mechanical and thermal properties are extensively as well as intensively measured. As a result, numerous publications in those areas are available at users' disposal.

With regard to the thermal radiative properties of these composites, it is unfortunate to find that there is nothing available, a very discouraging fact to workers in laser research. However, in view of the facts that the fiber materials are diffusion bonded between sheets of aluminum and the thickness of aluminum sheet is far more than enough to be opaque to the radiation, the thermal radiative properties of composite materials can be fully described by considering them as aluminum alone. Although aluminum alloys

2024-T851 and 6061-T6 are also commonly used as the matrix materials, the final products of the composites are usually alclad for corrosion resistance. Therefore, the generation of the most probable values on the thermal radiative properties of boron fiber aluminum matrix composite is based on the available data of aluminum.

Literature survey for aluminum revealed an adequate amount of data on the normal spectral emittance, reflectance, and absorptance. Measurement information and experimental results obtained in this survey are given in Tables 20-1 to 20-10 and Figures 20-1 to 20-5. By careful review of the tables and figures, one will see that the magnitudes of the thermal radiative properties are very much affected by the surface conditions of the specimens. The literature abounds with examples of test surfaces shown to be very sensitive to methods of preparation, thermal history, and environmental conditions. Despite this awareness, descriptions of test surfaces are generally inadequate because of our modest understanding of the mechanisms or real surface effects and how to properly characterize a surface.

To isolate the individual surface characteristics is a difficult task. For most materials it is not practical to alter one characteristic without causing an influence on another. The control of the many variables required to study surface characterization in a logical manner is a complex problem. As a result only the simplest of surface profiles or compositional effects have been studied or are understood. One of the most important influences on the radiative properties of metals arises from surface roughness.

Because of the difficulties mentioned above, data analysis and evaluation is not a straightforward task; some logical but not exact means should be used in the generation of the most probable values for the properties of our interest. It is decided that the classical model of Hagen and Rubens with some modification is used to interpret the selected emittance data for mechanically polished surfaces, which is chosen as a good approximation to the real surfaces. Details of modifying the Hagen and Rubens equation are discussed in Section 2 and Eq. (2.5-5) is used for data analysis.

Reliable and accurate available data on the normal spectral emittance of mechanically polished aluminum surface were obtained by converting the data sets, curves 4 and 5 of Figure 20-4, from absorptance to emittance using Kirchhoff's law. Data for curves 4 and 5 were obtained at temperatures of 573 K and 293 K respectively. By a least squares calculation Eq. (4.20-1) was found to fit the selected data with uncertainties of less than $\pm 10\%$. Absorptance and reflectance can be calculated by using Eqs. (4.20-2) and (4.20-3).

By a quick scanning review of the details on the available data and information given in Tables 20-1 to 20-10 and Figures 20-1 to 20-5, it appears that the surface roughness

can be incorporated into Eq. (4.20-1). However, no attempt was made because there was not a single systematic information on the roughness dependence of the radiative properties available for data analysis. As a result, only the radiative properties of mechanically polished surface are presented here. Note that in the following tables more decimal places are reported than warranted merely for the purpose of tabular smoothness and internal comparison. Readers are advised to use the appropriate uncertainties given in each case.

a. Normal Spectral Emittance (Wavelength Dependence)

Normal spectral emittance of mechanically polished boron fiber aluminum matrix composite is calculated from Eq. (4.20-1) and listed in Table 21-1 and plotted in Figure 21-1. The values generated are considered as provisional (about ±25% uncertainty) since they are estimated based on the aluminum data. Provisional values are presented at five temperatures, 293, 450, 600, 750, and 850 K. Note that the emittance is usually quite low and remains practically constant for wavelengths longer than 6 μm.

TABLE 21-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF BORON FIBER ALUMINUM MATRIX COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

λ	ϵ	λ	ϵ	λ	ϵ	λ	ϵ	λ	ϵ
MECHANICALLY POLISHED T = 293		MECHANICALLY POLISHED T = 450		MECHANICALLY POLISHED T = 600		MECHANICALLY POLISHED T = 750		MECHANICALLY POLISHED T = 850	
2.5	0.067	2.5	0.071	2.5	0.070	2.5	0.075	2.5	0.078
2.8	0.057	2.8	0.063	2.8	0.067	2.8	0.069	2.8	0.070
3.0	0.052	3.0	0.059	3.0	0.063	3.0	0.066	3.0	0.067
3.5	0.044	3.5	0.052	3.5	0.056	3.5	0.060	3.5	0.062
3.8	0.041	3.8	0.048	3.8	0.053	3.8	0.057	3.8	0.059
4.0	0.039	4.0	0.046	4.0	0.051	4.0	0.055	4.0	0.057
4.5	0.035	4.5	0.043	4.5	0.047	4.5	0.051	4.5	0.053
5.0	0.033	5.0	0.040	5.0	0.044	5.0	0.048	5.0	0.050
5.5	0.031	5.5	0.037	5.5	0.042	5.5	0.046	5.5	0.048
6.0	0.029	6.0	0.035	6.0	0.040	6.0	0.043	6.0	0.045
6.5	0.027	6.5	0.034	6.5	0.038	6.5	0.042	6.5	0.044
7.0	0.026	7.0	0.032	7.0	0.037	7.0	0.040	7.0	0.042
7.5	0.025	7.5	0.031	7.5	0.035	7.5	0.039	7.5	0.040
8.0	0.024	8.0	0.030	8.0	0.034	8.0	0.037	8.0	0.039
8.5	0.023	8.5	0.029	8.5	0.033	8.5	0.036	8.5	0.038
9.0	0.023	9.0	0.028	9.0	0.032	9.0	0.035	9.0	0.037
9.5	0.022	9.5	0.027	9.5	0.031	9.5	0.034	9.5	0.036
10.0	0.021	10.0	0.026	10.0	0.030	10.0	0.033	10.0	0.035
10.5	0.021	10.5	0.026	10.5	0.029	10.5	0.032	10.5	0.034
11.0	0.020	11.0	0.025	11.0	0.029	11.0	0.032	11.0	0.033
11.5	0.020	11.5	0.025	11.5	0.028	11.5	0.031	11.5	0.033
12.0	0.019	12.0	0.024	12.0	0.028	12.0	0.030	12.0	0.032
12.5	0.019	12.5	0.024	12.5	0.027	12.5	0.030	12.5	0.031
13.0	0.019	13.0	0.023	13.0	0.026	13.0	0.029	13.0	0.031
13.5	0.018	13.5	0.023	13.5	0.026	13.5	0.029	13.5	0.030
14.0	0.018	14.0	0.022	14.0	0.025	14.0	0.028	14.0	0.030
14.5	0.017	14.5	0.022	14.5	0.025	14.5	0.028	14.5	0.029
15.0	0.017	15.0	0.021	15.0	0.025	15.0	0.027	15.0	0.029

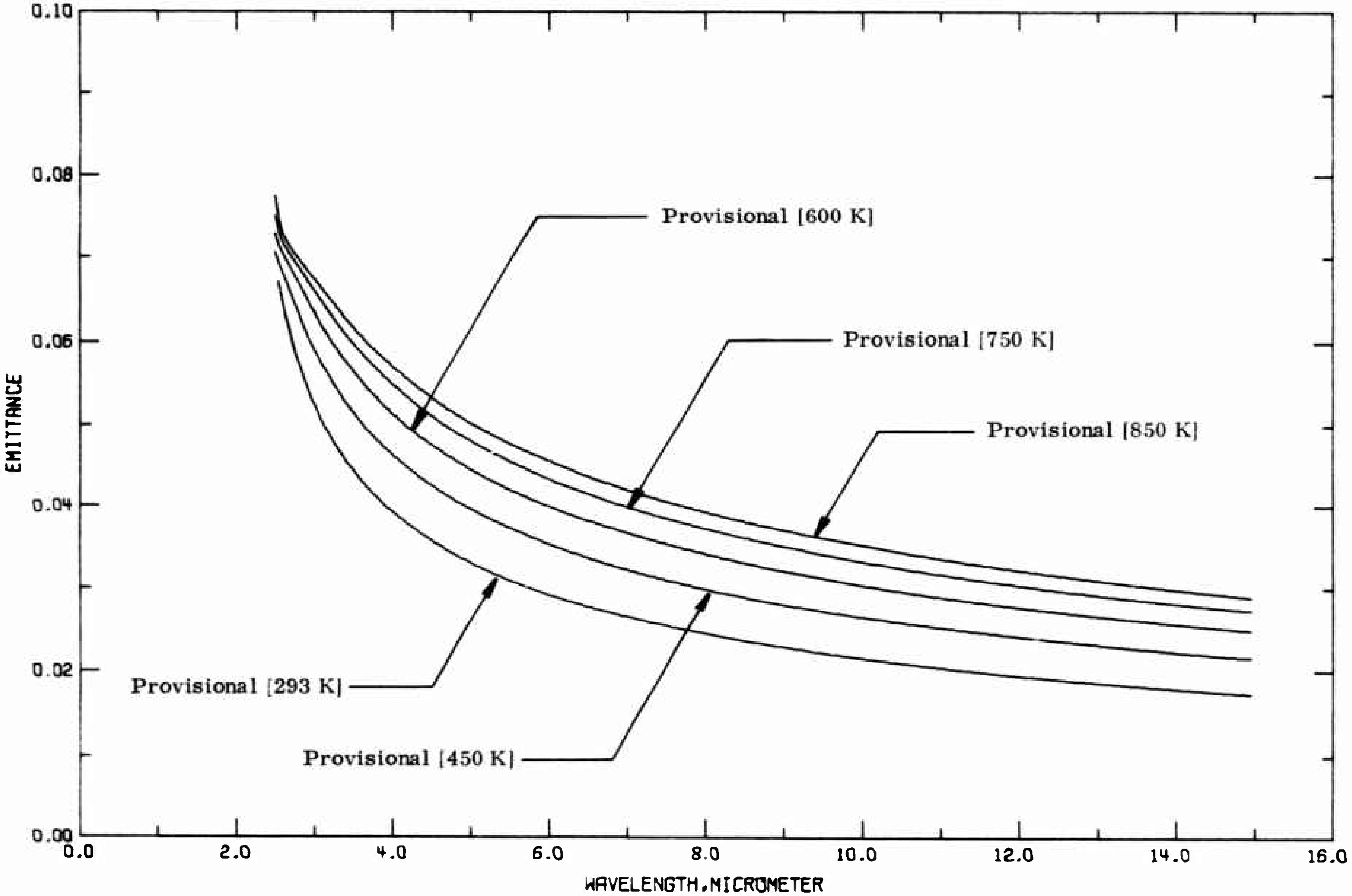


FIGURE 21-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF BORON FIBER ALUMINUM MATRIX COMPOSITE (WAVELENGTH DEPENDENCE).

b. Normal Spectral Emittance (Temperature Dependence)

The normal spectral emittance as a function of temperature is given in Table 21-2 and Figure 21-2. The generated values are considered as provisional with uncertainty ±25%. The plot clearly shows that emittance for a given wavelength does not vary appreciably for a wide temperature range. Note that the melting point of aluminum at about 930 K is not far from the ending point (about 880 K) of each curve. It seems that the curves can be extrapolated to or beyond the melting point.

TABLE 21-2. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF BORON FIBER ALUMINUM MATRIX COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ	T	ϵ	T	ϵ	T	ϵ
MECHANICALLY POLISHED λ = 2.8		MECHANICALLY POLISHED λ = 3.6		MECHANICALLY POLISHED λ = 5.0		MECHANICALLY POLISHED λ = 10.6	
250.0	0.054	250.0	0.038	250.0	0.030	250.0	0.019
293.0	0.057	293.0	0.041	293.0	0.033	293.0	0.021
300.0	0.057	300.0	0.041	300.0	0.033	300.0	0.021
350.0	0.060	350.0	0.044	350.0	0.036	350.0	0.023
400.0	0.062	400.0	0.046	400.0	0.038	400.0	0.024
450.0	0.063	450.0	0.048	450.0	0.040	450.0	0.026
500.0	0.065	500.0	0.050	500.0	0.041	500.0	0.027
550.0	0.066	550.0	0.052	550.0	0.043	550.0	0.028
600.0	0.067	600.0	0.053	600.0	0.044	600.0	0.029
650.0	0.068	650.0	0.055	650.0	0.046	650.0	0.030
700.0	0.068	700.0	0.056	700.0	0.047	700.0	0.031
750.0	0.069	750.0	0.057	750.0	0.048	750.0	0.032
800.0	0.069	800.0	0.058	800.0	0.049	800.0	0.033
850.0	0.070	850.0	0.059	650.0	0.050	650.0	0.034
680.0	0.070	880.0	0.059	880.0	0.051	880.0	0.035

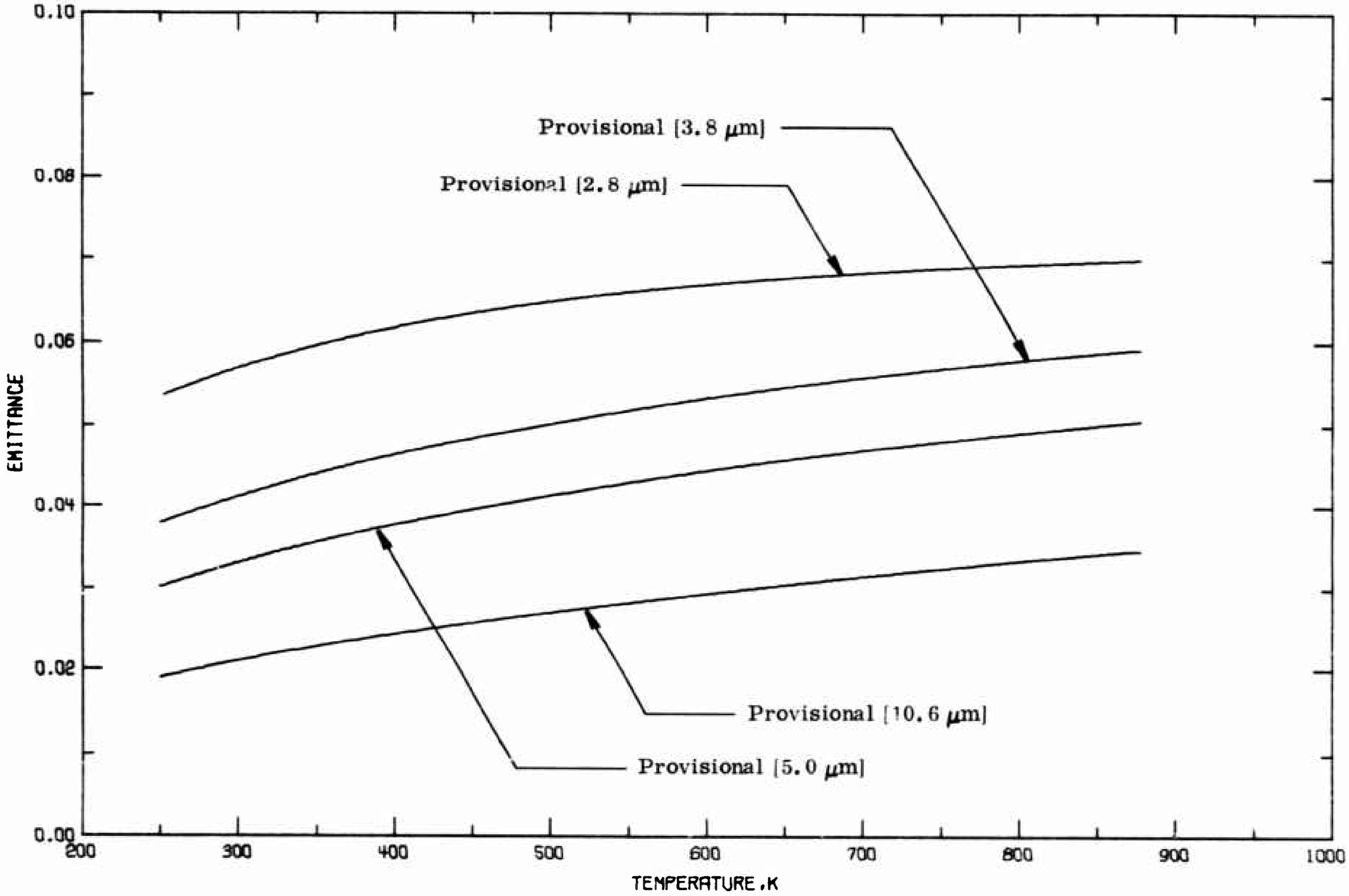


FIGURE 21-2. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF BORON FIBER ALUMINUM MATRIX COMPOSITE (TEMPERATURE DEPENDENCE).

c. Normal Spectral Reflectance (Wavelength Dependence)

As given in Table 21-3 and plotted in Figure 21-3, the normal spectral reflectance of boron fiber aluminum composite is calculated by assuming that energy loss of the impinging radiation is entirely due to absorption. The result is remarkably good as one can see by comparing Figure 20-3 and Figure 21-3. Since the data analysis is totally based on the available data of aluminum, allowance is given in the estimation of the predicted values. An estimated uncertainty of ±20% is given to the calculated values.

TABLE 21-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF BORON FIBER ALUMINUM MATRIX COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
MECHANICALLY POLISHED T = 293		MECHANICALLY POLISHED T = 450		MECHANICALLY POLISHED T = 600		MECHANICALLY POLISHED T = 750		MECHANICALLY POLISHED T = 850	
2.5	0.933	2.5	0.929	2.5	0.927	2.5	0.925	2.5	0.922
2.8	0.943	2.8	0.937	2.8	0.933	2.8	0.931	2.8	0.930
3.0	0.948	3.0	0.941	3.0	0.937	3.0	0.934	3.0	0.933
3.5	0.956	3.5	0.946	3.5	0.944	3.5	0.940	3.5	0.938
3.8	0.959	3.8	0.952	3.8	0.947	3.8	0.943	3.8	0.941
4.0	0.961	4.0	0.954	4.0	0.949	4.0	0.945	4.0	0.943
4.5	0.965	4.5	0.957	4.5	0.953	4.5	0.949	4.5	0.947
5.0	0.967	5.0	0.960	5.0	0.956	5.0	0.952	5.0	0.950
5.5	0.969	5.5	0.963	5.5	0.958	5.5	0.954	5.5	0.952
6.0	0.971	6.0	0.965	6.0	0.960	6.0	0.957	6.0	0.955
6.5	0.973	6.5	0.966	6.5	0.962	6.5	0.958	6.5	0.956
7.0	0.974	7.0	0.968	7.0	0.963	7.0	0.960	7.0	0.958
7.5	0.975	7.5	0.969	7.5	0.965	7.5	0.961	7.5	0.960
8.0	0.976	8.0	0.970	8.0	0.966	8.0	0.963	8.0	0.961
8.5	0.977	8.5	0.971	8.5	0.967	8.5	0.964	8.5	0.962
9.0	0.977	9.0	0.972	9.0	0.968	9.0	0.965	9.0	0.963
9.5	0.978	9.5	0.973	9.5	0.969	9.5	0.965	9.5	0.964
10.0	0.979	10.0	0.974	10.0	0.970	10.0	0.967	10.0	0.965
10.5	0.979	10.5	0.974	10.5	0.971	10.5	0.968	10.5	0.966
11.0	0.980	11.0	0.975	11.0	0.971	11.0	0.968	11.0	0.967
11.5	0.980	11.5	0.975	11.5	0.972	11.5	0.969	11.5	0.967
12.0	0.981	12.0	0.976	12.0	0.972	12.0	0.970	12.0	0.968
12.5	0.981	12.5	0.976	12.5	0.973	12.5	0.970	12.5	0.969
13.0	0.981	13.0	0.977	13.0	0.974	13.0	0.971	13.0	0.969
13.5	0.982	13.5	0.977	13.5	0.974	13.5	0.971	13.5	0.970
14.0	0.982	14.0	0.978	14.0	0.975	14.0	0.972	14.0	0.970
14.5	0.983	14.5	0.978	14.5	0.975	14.5	0.972	14.5	0.971
15.0	0.983	15.0	0.979	15.0	0.975	15.0	0.973	15.0	0.971

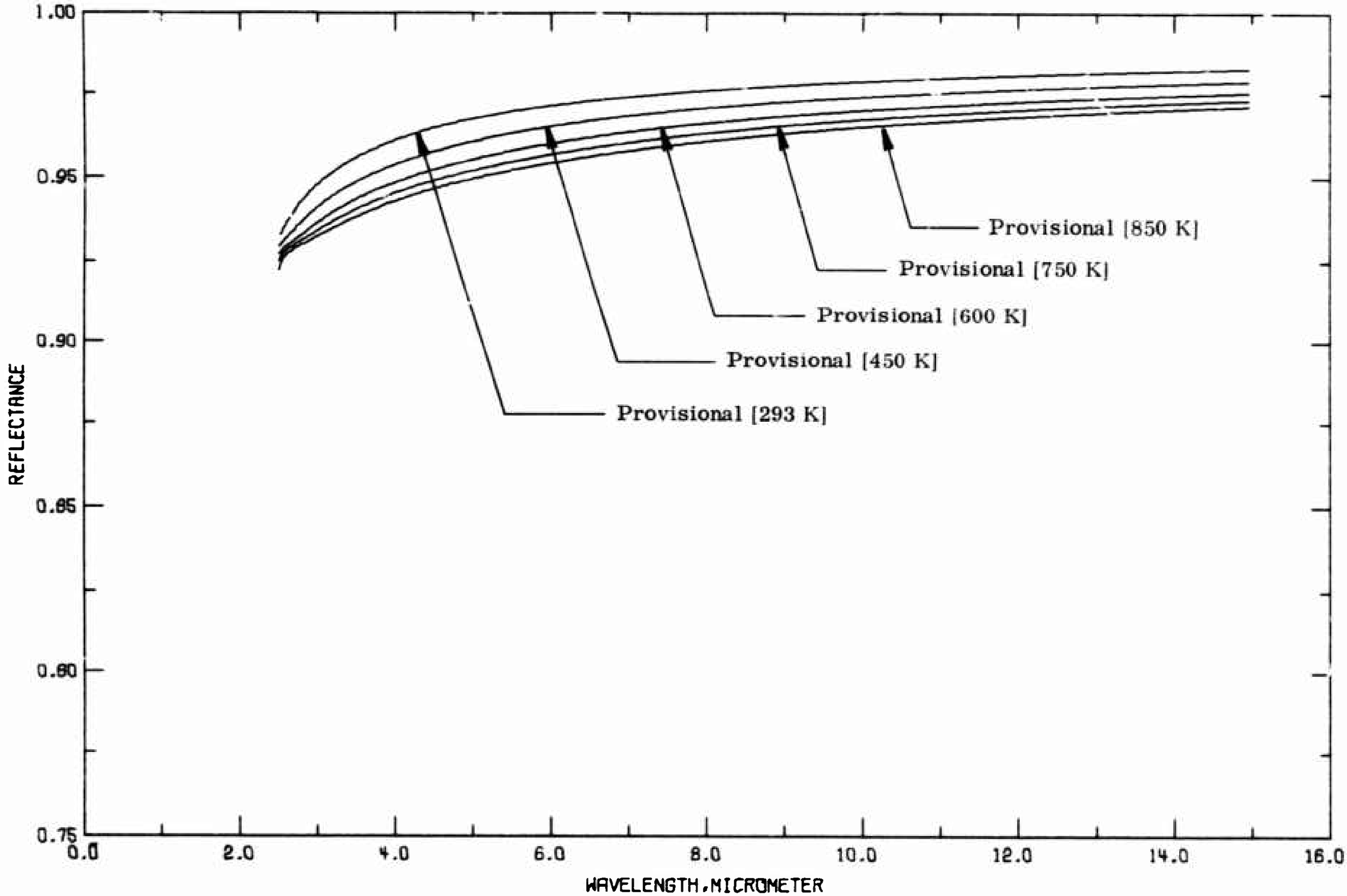


FIGURE 21-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF BORON FIBER ALUMINUM MATRIX COMPOSITE (WAVELENGTH DEPENDENCE).

d. Normal Spectral Reflectance (Temperature Dependence)

In Table 21-4, the provisional values of the normal spectral reflectance are given with estimated uncertainties of ± 20%. The variation of the property as a function of temperature is demonstrated in Figure 21-4. For a given wavelength, the normal spectral reflectance remains as a constant from room temperature up to near the melting point of the material. At higher temperatures our knowledge on this property is lacking. However, it seems that a linear extrapolation of the curve to and above the melting point can be used with uncertainty of no more than ± 35%.

TABLE 21-4. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF BORON FIBER ALUMINUM MATRIX COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

T	ρ	T	ρ	T	ρ	T	ρ
MECHANICALLY POLISHED λ = 2.8		MECHANICALLY POLISHED λ = 3.8		MECHANICALLY POLISHED λ = 5.0		MECHANICALLY POLISHED λ = 10.6	
250.0	0.946	250.0	0.962	250.0	0.970	250.0	0.981
293.0	0.943	293.0	0.959	293.0	0.967	293.0	0.979
300.0	0.943	300.0	0.959	300.0	0.967	300.0	0.979
350.0	0.940	350.0	0.956	350.0	0.964	350.0	0.977
400.0	0.938	400.0	0.954	400.0	0.962	400.0	0.976
450.0	0.937	450.0	0.952	450.0	0.960	450.0	0.974
500.0	0.935	500.0	0.950	500.0	0.959	500.0	0.973
550.0	0.934	550.0	0.948	550.0	0.957	550.0	0.972
600.0	0.933	600.0	0.947	600.0	0.956	600.0	0.971
650.0	0.932	650.0	0.945	650.0	0.954	650.0	0.970
700.0	0.932	700.0	0.944	700.0	0.953	700.0	0.969
750.0	0.931	750.0	0.943	750.0	0.952	750.0	0.968
800.0	0.931	800.0	0.942	800.0	0.951	800.0	0.967
850.0	0.930	850.0	0.941	850.0	0.950	850.0	0.966
880.0	0.930	880.0	0.941	880.0	0.949	880.0	0.965

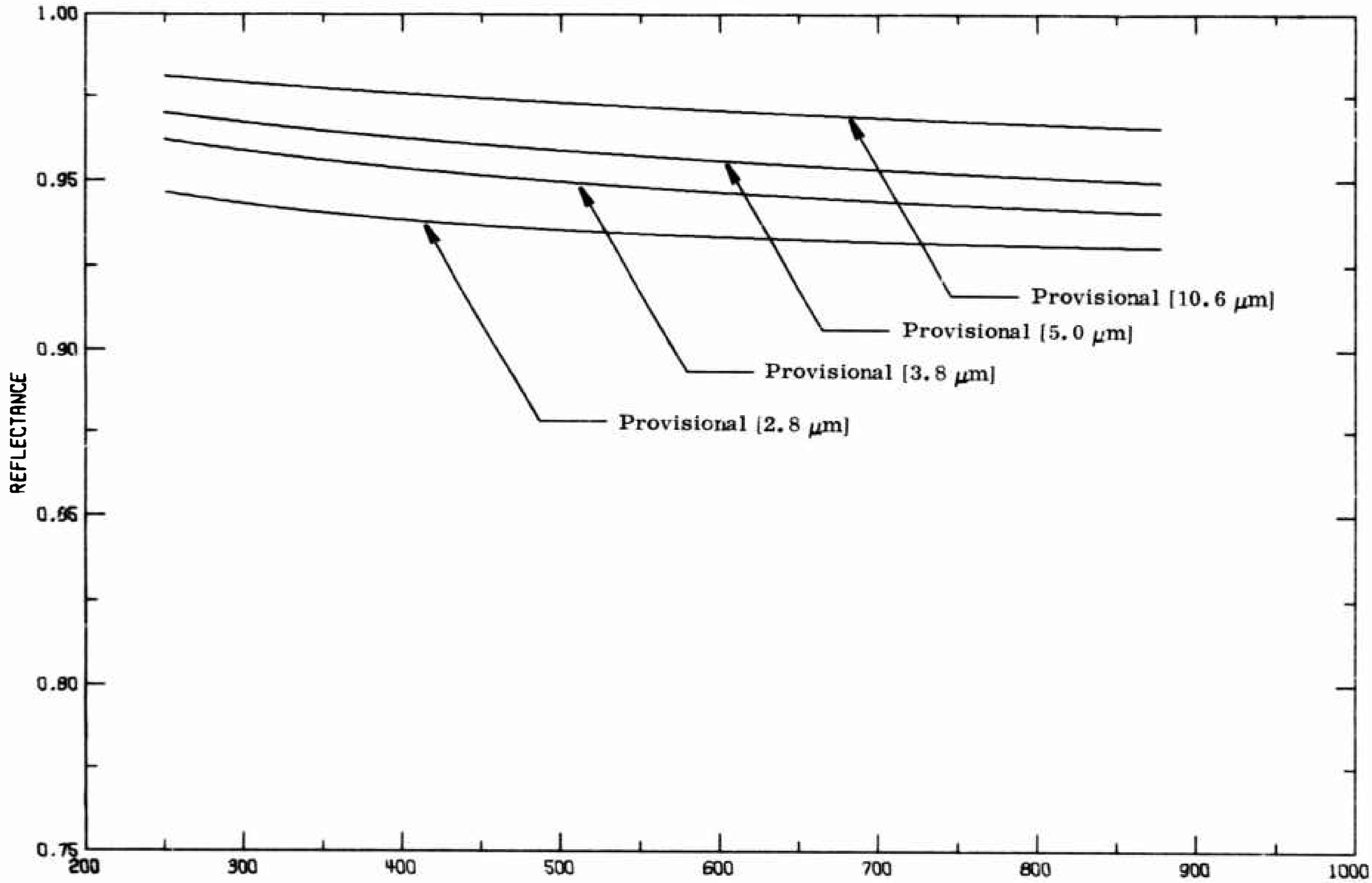


FIGURE 21-4. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF BORON FIBER ALUMINUM MATRIX COMPOSITE (TEMPERATURE DEPENDENCE).

e. Normal Spectral Absorptance (Wavelength Dependence)

The normal spectral absorptance is obtained according to the Kirchhoff's law, i.e., numerically the absorptance is equal to the emittance. As a result, Table 21-5 and Figure 21-5 appear the same as Table 21-1 and Figure 21-1, as well as the uncertainties (±25%). The absorptance varies appreciably for wavelengths lower than 4.0 μm and remains practically unchanged for longer wavelengths as shown in Figure 21-5.

TABLE 21-5. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF BORON FIBER ALUMINUM MATRIX COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α	λ	α	λ	α
MECHANICALLY POLISHED T = 293		MECHANICALLY POLISHED T = 450		MECHANICALLY POLISHED T = 600		MECHANICALLY POLISHED T = 750		MECHANICALLY POLISHED T = 850	
2.5	0.067	2.5	0.071	2.5	0.073	2.5	0.075	2.5	0.078
2.8	0.057	2.8	0.063	2.8	0.067	2.8	0.069	2.8	0.070
3.0	0.052	3.0	0.059	3.0	0.063	3.0	0.066	3.0	0.067
3.5	0.044	3.5	0.052	3.5	0.056	3.5	0.060	3.5	0.062
3.8	0.041	3.8	0.048	3.8	0.053	3.8	0.057	3.8	0.059
4.0	0.039	4.0	0.046	4.0	0.051	4.0	0.055	4.0	0.057
4.5	0.035	4.5	0.043	4.5	0.047	4.5	0.051	4.5	0.053
5.0	0.033	5.0	0.040	5.0	0.044	5.0	0.048	5.0	0.050
5.5	0.031	5.5	0.037	5.5	0.042	5.5	0.046	5.5	0.048
6.0	0.029	6.0	0.035	6.0	0.040	6.0	0.043	6.0	0.045
6.5	0.027	6.5	0.034	6.5	0.038	6.5	0.042	6.5	0.044
7.0	0.026	7.0	0.032	7.0	0.037	7.0	0.040	7.0	0.042
7.5	0.025	7.5	0.031	7.5	0.035	7.5	0.039	7.5	0.040
8.0	0.024	8.0	0.030	8.0	0.034	8.0	0.037	8.0	0.039
8.5	0.023	8.5	0.029	8.5	0.033	8.5	0.036	8.5	0.038
9.0	0.023	9.0	0.028	9.0	0.032	9.0	0.035	9.0	0.037
9.5	0.022	9.5	0.027	9.5	0.031	9.5	0.034	9.5	0.036
10.0	0.021	10.0	0.026	10.0	0.030	10.0	0.033	10.0	0.035
10.5	0.021	10.5	0.026	10.5	0.029	10.5	0.032	10.5	0.034
11.0	0.020	11.0	0.025	11.0	0.029	11.0	0.032	11.0	0.033
11.5	0.020	11.5	0.025	11.5	0.028	11.5	0.031	11.5	0.033
12.0	0.019	12.0	0.024	12.0	0.028	12.0	0.030	12.0	0.032
12.5	0.019	12.5	0.024	12.5	0.027	12.5	0.030	12.5	0.031
13.0	0.019	13.0	0.023	13.0	0.026	13.0	0.029	13.0	0.031
13.5	0.018	13.5	0.023	13.5	0.026	13.5	0.029	13.5	0.030
14.0	0.018	14.0	0.022	14.0	0.025	14.0	0.028	14.0	0.030
14.5	0.017	14.5	0.022	14.5	0.025	14.5	0.028	14.5	0.029
15.0	0.017	15.0	0.021	15.0	0.025	15.0	0.027	15.0	0.029

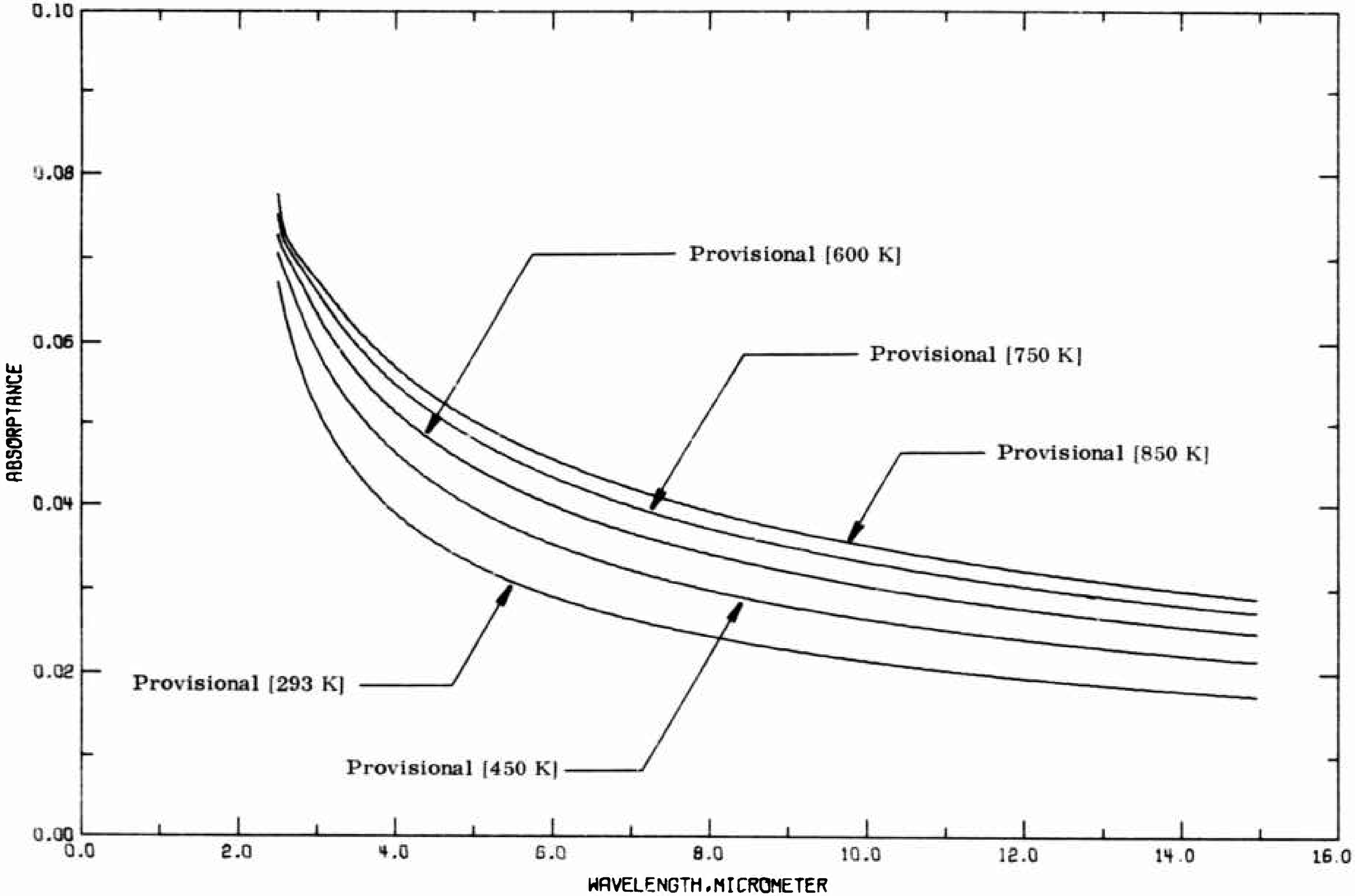


FIGURE 21-5. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF BORON FIBER ALUMINUM MATRIX COMPOSITE (WAVELENGTH DEPENDENCE).

f. Normal Spectral Absorptance (Temperature Dependence)

The provisional values of the normal spectral absorptance of boron fiber aluminum matrix composite is given in Table 21-6 and plotted in Figure 21-6. They are numerically equal to the normal spectral emittance. In Figure 21-6, our predicted curves for 5.0 μm and 10.0 μm are higher than experimental values plotted in Figure 20-5. By a careful examination of the measurement information, one sees that the experimental points in Figure 20-5 are for thin films. The absorptance of bulk material is in general higher than that of thin film. An uncertainty of 25% is given to the provisional values so that they can be used for most of the real surfaces.

TABLE 21-6. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF BORON FIBER ALUMINUM MATRIX COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

T	α	T	α	T	α	T	α
MECHANICALLY POLISHED λ = 2.8		MECHANICALLY POLISHED λ = 3.8		MECHANICALLY POLISHED λ = 5.0		MECHANICALLY POLISHED λ = 10.6	
250.0	0.054	250.0	0.038	250.0	0.030	250.0	0.019
293.0	0.057	293.0	0.041	293.0	0.033	293.0	0.021
300.0	0.057	300.0	0.041	300.0	0.033	300.0	0.021
350.0	0.060	350.0	0.044	350.0	0.036	350.0	0.023
400.0	0.062	400.0	0.046	400.0	0.038	400.0	0.024
450.0	0.063	450.0	0.048	450.0	0.040	450.0	0.026
500.0	0.065	500.0	0.050	500.0	0.041	500.0	0.027
550.0	0.066	550.0	0.052	550.0	0.043	550.0	0.028
600.0	0.067	600.0	0.053	600.0	0.044	600.0	0.029
650.0	0.068	650.0	0.055	650.0	0.046	650.0	0.030
700.0	0.068	700.0	0.056	700.0	0.047	700.0	0.031
750.0	0.069	750.0	0.057	750.0	0.048	750.0	0.032
800.0	0.069	800.0	0.058	800.0	0.049	800.0	0.033
850.0	0.070	850.0	0.059	850.0	0.050	850.0	0.034
880.0	0.070	880.0	0.059	880.0	0.051	880.0	0.035

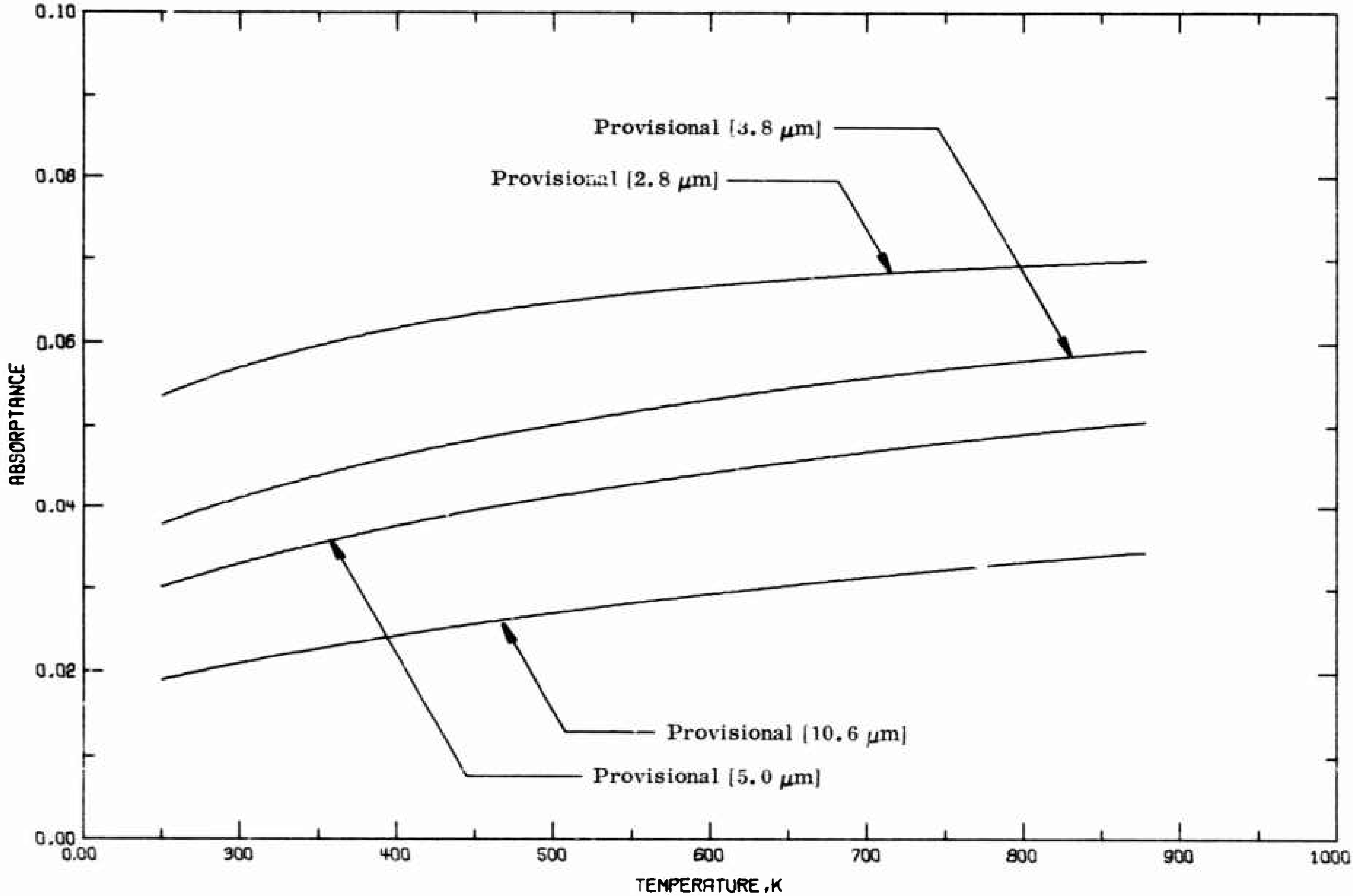


FIGURE 21-6. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF BORON FIBER ALUMINUM MATRIX COMPOSITE (TEMPERATURE DEPENDENCE).

g. Transmittance

Although it is true that metals in the form of extremely thin films may be transparent for a wide wavelength range, they are opaque if the thickness is greater than several hundred angstroms. Consequently, composites with metal matrix are opaque to visible and infrared radiation because in general applications they are not used as extremely thin films. This leads to the conclusion that as an aircraft/spacecraft structural material, this composite is opaque and its transmittance is zero.

4.22. Graphite Fiber Aluminum Matrix Composite

Graphite fiber aluminum matrix composite is made in the form of sheet or tape. The sheets are made by diffusion bonding graphite fibers between two sheets of aluminum or aluminum alloys. The tape is made by plasma spraying the 713 braze alloys. The tape is then diffusion or braze bonded into any desired configuration.

There are three types of graphite fibers currently in large-scale production. These filaments have varied tensile strengths, moduli of elasticity, and densities. Graphite fibers for use in composite materials are made by the carbonization of organic fibers. Polyacrylonitrile (PAN) is most commonly used today, but acrylic and rayon fibers have been used to some extent in the past. The mechanical properties of the fibers depend on the temperatures used in the carbonization process. Temperatures of 2800-3300 K yield fibers with high moduli of elasticity but with relatively low tensile strength while temperatures of 1800-2300 K result in fibers of the highest tensile strength but only moderate elasticity. The melting point of the graphite fibers is much higher than the aluminum matrix components generally used. The fibers are available in short lengths (about 48 inches) and continuous lengths up to 3000 feet. The mechanical properties of these two forms are somewhat different.

In the area of metal matrix, aluminum or aluminum alloys are currently commercially available.

The advantage of the graphite fiber aluminum matrix composite is that along with its light weight it has a high temperature and heat resistance. Although the fiber material stands very high temperatures, its aluminum composite is not recommended for continuous service above 590 K, but the intermittent service to 645 K is possible. The products are available commercially in a wide range of laminate thickness including monolayer sheets in finished form. Virtually all of the actual hardware items built to date have been fabricated using standard fiber volume fractions of fifty percent.

The composite materials are fabricated primarily for aircraft constructions because of their advantages. Much of their mechanical and thermal properties are extensively as well as intensively measured. As a result, numerous publications in those areas are available at users' disposal.

With regard to the thermal radiative properties of these composites, it is unfortunate to find that there is nothing available, a very discouraging fact to workers in laser research. However, in view of the facts that the fiber materials are diffusion bonded between sheets of aluminum and the thickness of aluminum sheet is far more than

enough to be opaque to the radiation, the thermal radiative properties of composite materials can be fully described by considering them as aluminum alone. Although aluminum alloys 2024-T851 and 6061-T6 are also commonly used as the matrix materials, the final products of the composites are usually alclad for corrosion resistance. Therefore, the generation of the most probable values on the thermal radiative properties of graphite fiber aluminum matrix composite is based on the available data of aluminum.

Literature survey for aluminum revealed an adequate amount of data on the normal spectral emittance, reflectance, and absorptance. Measurement information and experimental results obtained in this survey are given in Tables 20-1 to 20-10 and Figures 20-1 to 20-5. By careful review of the tables and figures, one will see that the magnitudes of the thermal radiative properties are very much affected by the surface conditions of the specimens. The literature abounds with examples of test surfaces shown to be very sensitive to methods of preparation, thermal history, and environmental conditions. Despite this awareness, descriptions of test surfaces are generally inadequate because of our modest understanding of the mechanisms or real surface effects and how to properly characterize a surface.

To isolate the individual surface characteristics is a difficult task. For most materials it is not practical to alter one characteristic without causing an influence on another. The control of the many variables required to study surface characterization in a logical manner is a complex problem. As a result only the simplest of surface profiles or compositional effects have been studied or are understood. One of the most important influences on the radiative properties of metals arises from surface roughness.

Because of the difficulties mentioned above, data analysis and evaluation is not a straightforward task; some logical but not exact means should be used in the generation of the most probable values for the properties of our interest. It is decided that the classical model of Hagen and Rubens with some modification is used to interpret the selected emittance data for mechanically polished surfaces, which is chosen as a good approximation to the real surfaces. Details of modifying the Hagen and Rubens equation are discussed in Section 2 and Eq. (2.5-5) is used for data analysis.

Reliable and accurate available data on the normal spectral emittance of mechanically polished aluminum surface were obtained by converting the data sets, curves 4 and 5 of Figure 20-4, from absorptance to emittance using Kirchhoff's law. Data for curves 4 and 5 were obtained at temperatures of 573 K and 293 K respectively. By a least squares calculation Eq. (4.20-1) was found to fit the selected data with uncertainties of less than $\pm 10\%$. Absorptance and reflectance can be calculated by using Eqs. (4.20-2) and (4.20-3).

By a quick scanning review of the details on the available data and information given in Tables 20-1 to 20-10 and Figures 20-1 to 20-5, it appears that the surface roughness can be incorporated into Eq. (4.20-1). However, no attempt was made because there was not a single systematic information on the roughness dependence of the radiative properties available for data analysis. As a result, only the radiative properties of mechanically polished surface are presented here. Note that in the following tables more decimal places are reported than warranted merely for the purpose of tabular smoothness and internal comparison. Readers are advised to use the appropriate uncertainties given in each case.

a. Normal Spectral Emittance (Wavelength Dependence)

Normal spectral emittance of mechanically polished graphite fiber aluminum matrix composite is calculated from Eq. (4.20-1) and listed in Table 22-1 and plotted in Figure 22-1. The values generated are considered as provisional (about $\pm 25\%$ uncertainty) since they are estimated based on the aluminum data. Provisional values are presented at five temperatures, 293, 450, 600, 750, and 850 K. Note that the emittance is usually quite low and remains practically constant for wavelengths longer than 6 μm.

TABLE 22-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF GRAPHITE FIBER ALUMINUM MATRIX COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

λ	ϵ	λ	ϵ	λ	ϵ	λ	ϵ	λ	ϵ
MECHANICALLY POLISHED T = 293		MECHANICALLY POLISHED T = 450		MECHANICALLY POLISHED T = 600		MECHANICALLY POLISHED T = 750		MECHANICALLY POLISHED T = 850	
2.5	0.067	2.5	0.071	2.5	0.073	2.5	0.075	2.5	0.076
2.8	0.057	2.8	0.063	2.8	0.067	2.8	0.069	2.8	0.070
3.0	0.052	3.0	0.059	3.0	0.063	3.0	0.065	3.0	0.067
3.5	0.044	3.5	0.052	3.5	0.056	3.5	0.060	3.5	0.062
3.8	0.041	3.8	0.048	3.8	0.053	3.8	0.057	3.8	0.059
4.0	0.039	4.0	0.046	4.0	0.051	4.0	0.055	4.0	0.057
4.5	0.035	4.5	0.043	4.5	0.047	4.5	0.051	4.5	0.053
5.0	0.033	5.0	0.040	5.0	0.044	5.0	0.048	5.0	0.050
5.5	0.031	5.5	0.037	5.5	0.042	5.5	0.046	5.5	0.048
6.0	0.029	6.0	0.035	6.0	0.040	6.0	0.043	6.0	0.045
6.5	0.027	6.5	0.034	6.5	0.038	6.5	0.042	6.5	0.044
7.0	0.026	7.0	0.032	7.0	0.037	7.0	0.040	7.0	0.042
7.5	0.025	7.5	0.031	7.5	0.035	7.5	0.039	7.5	0.040
8.0	0.024	8.0	0.030	8.0	0.034	8.0	0.037	8.0	0.039
8.5	0.023	8.5	0.029	8.5	0.033	8.5	0.036	8.5	0.038
9.0	0.023	9.0	0.028	9.0	0.032	9.0	0.035	9.0	0.037
9.5	0.022	9.5	0.027	9.5	0.031	9.5	0.034	9.5	0.036
10.0	0.021	10.0	0.026	10.0	0.030	10.0	0.033	10.0	0.035
10.5	0.021	10.5	0.026	10.5	0.029	10.5	0.032	10.5	0.034
11.0	0.020	11.0	0.025	11.0	0.029	11.0	0.032	11.0	0.033
11.5	0.020	11.5	0.025	11.5	0.028	11.5	0.031	11.5	0.033
12.0	0.019	12.0	0.024	12.0	0.028	12.0	0.030	12.0	0.032
12.5	0.019	12.5	0.024	12.5	0.027	12.5	0.030	12.5	0.031
13.0	0.019	13.0	0.023	13.0	0.026	13.0	0.029	13.0	0.031
13.5	0.018	13.5	0.023	13.5	0.026	13.5	0.029	13.5	0.030
14.0	0.018	14.0	0.022	14.0	0.025	14.0	0.028	14.0	0.030
14.5	0.017	14.5	0.022	14.5	0.025	14.5	0.028	14.5	0.029
15.0	0.017	15.0	0.021	15.0	0.025	15.0	0.027	15.0	0.029

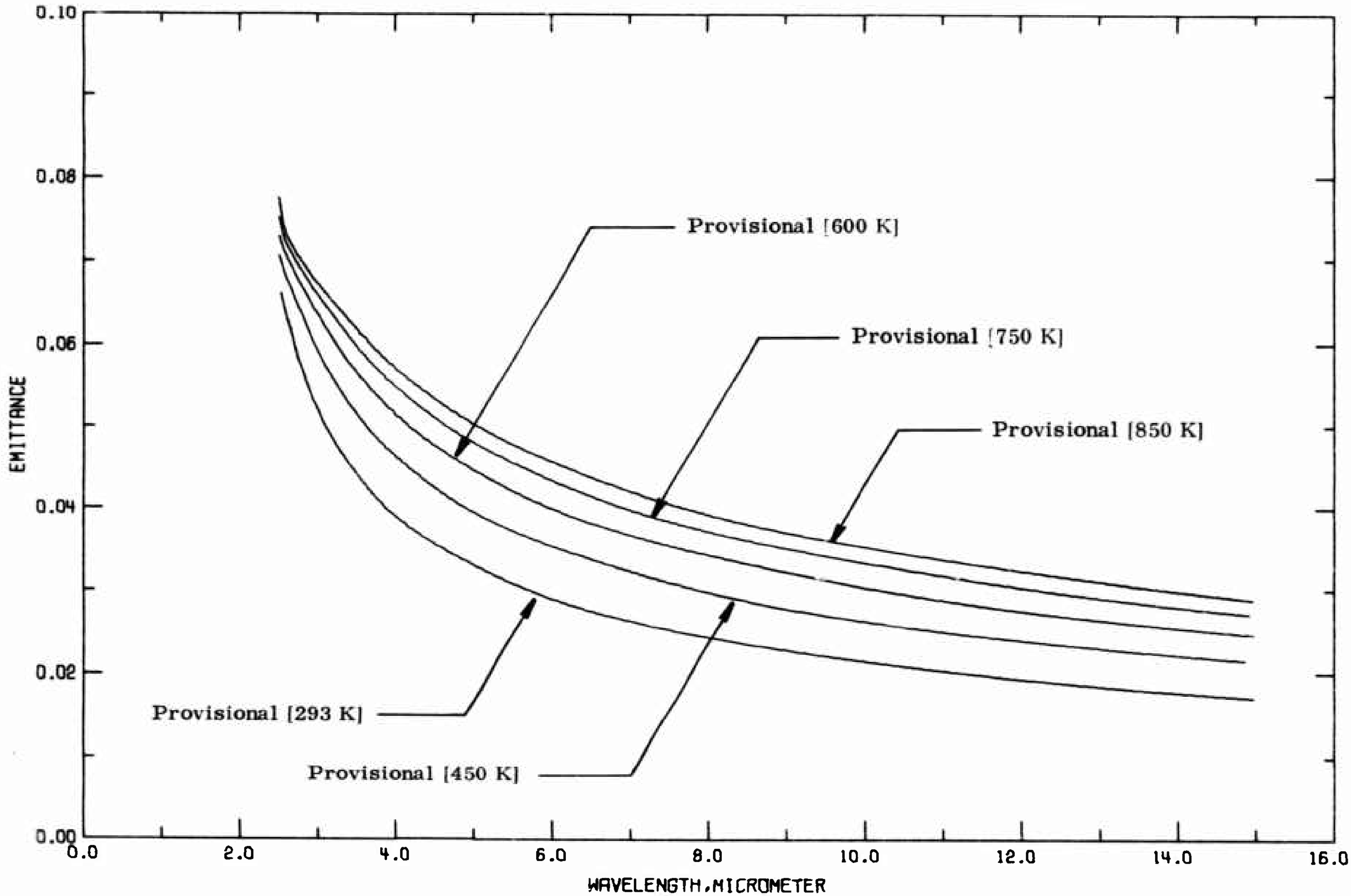


FIGURE 22-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF GRAPHITE FIBER ALUMINUM MATRIX COMPOSITE (WAVELENGTH DEPENDENCE).

b. Normal Spectral Emittance (Temperature Dependence)

The normal spectral emittance as a function of temperature is given in Table 22-2 and Figure 22-2. The generated values are considered as provisional with ± 25% uncertainty. The plot clearly shows that emittance for a given wavelength does not vary appreciably for a wide temperature range. Note that the melting point of aluminum at about 930 K is not far from the ending point (about 880 K) of each curve. It seems that the curves can be extrapolated to or beyond the melting point.

TABLE 22-2. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF GRAPHITE FIBER ALUMINUM MATRIX COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ	T	ϵ	T	ϵ	T	ϵ
CHANICALLY LISHED λ = 2.8		MECHANICALLY POLISHED λ = 3.8		MECHANICALLY POLISHED λ = 5.0		MECHANICALLY POLISHED λ = 10.6	
250.0	0.054	250.0	0.038	250.0	0.030	250.0	0.019
293.0	0.057	293.0	0.041	293.0	0.033	293.0	0.021
300.0	0.057	300.0	0.041	300.0	0.033	300.0	0.021
350.0	0.060	350.0	0.044	350.0	0.036	350.0	0.023
400.0	0.062	400.0	0.046	400.0	0.038	400.0	0.024
450.0	0.063	450.0	0.048	450.0	0.040	450.0	0.026
500.0	0.065	500.0	0.050	500.0	0.041	500.0	0.027
550.0	0.066	550.0	0.052	550.0	0.043	550.0	0.028
600.0	0.067	600.0	0.053	600.0	0.044	600.0	0.029
650.0	0.068	650.0	0.055	650.0	0.046	650.0	0.030
700.0	0.068	700.0	0.056	700.0	0.047	700.0	0.031
750.0	0.069	750.0	0.057	750.0	0.048	750.0	0.032
800.0	0.069	800.0	0.058	800.0	0.049	800.0	0.033
850.0	0.070	850.0	0.059	850.0	0.050	850.0	0.034
880.0	0.070	880.0	0.059	880.0	0.051	880.0	0.035

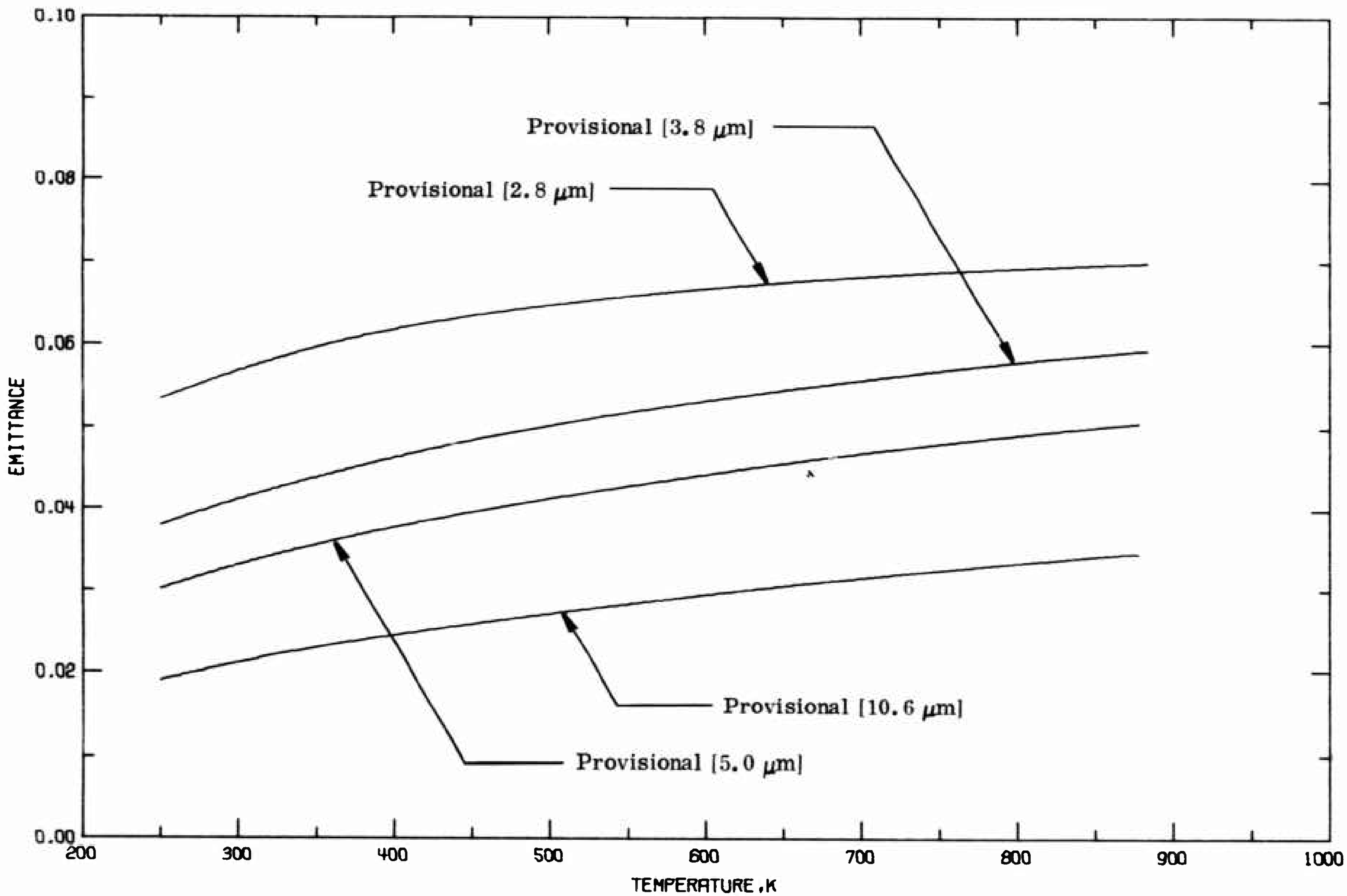


FIGURE 22-2. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF GRAPHITE FIBER ALUMINUM MATRIX COMPOSITE (TEMPERATURE DEPENDENCE).

c. Normal Spectral Reflectance (Wavelength Dependence)

As given in Table 22-3 and plotted in Figure 22-3 the normal spectral reflectance of graphite fiber aluminum matrix composite is calculated by assuming that energy loss of the impinging radiation is entirely due to absorption. Since the data analysis is totally based on the available data of aluminum, allowance is given in the estimation of the predicted values. An estimated uncertainty of ±20% is given to the calculated values.

TABLE 22-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF GRAPHITE FIBER ALUMINUM MATRIX COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ	λ	ρ	λ	ρ
MECHANICALLY POLISHED T = 293		MECHANICALLY POLISHED T = 450		MECHANICALLY POLISHED T = 600		MECHANICALLY POLISHED T = 750		MECHANICALLY POLISHED T = 850	
2.5	0.933	2.5	0.929	2.5	0.927	2.5	0.925	2.5	0.922
2.6	0.943	2.8	0.937	2.8	0.933	2.8	0.931	2.8	0.930
3.0	0.948	3.0	0.941	3.0	0.937	3.0	0.934	3.0	0.933
3.5	0.956	3.5	0.946	3.5	0.944	3.5	0.940	3.5	0.938
3.8	0.959	3.8	0.952	3.8	0.947	3.8	0.943	3.8	0.941
4.0	0.961	4.0	0.954	4.0	0.949	4.0	0.945	4.0	0.943
4.5	0.965	4.5	0.957	4.5	0.953	4.5	0.949	4.5	0.947
5.0	0.967	5.0	0.960	5.0	0.956	5.0	0.952	5.0	0.950
5.5	0.969	5.5	0.963	5.5	0.958	5.5	0.954	5.5	0.952
6.0	0.971	6.0	0.965	6.0	0.960	6.0	0.957	6.0	0.955
6.5	0.973	6.5	0.966	6.5	0.962	6.5	0.958	6.5	0.956
7.0	0.974	7.0	0.968	7.0	0.963	7.0	0.960	7.0	0.958
7.5	0.975	7.5	0.969	7.5	0.965	7.5	0.961	7.5	0.960
8.0	0.976	8.0	0.970	8.0	0.966	8.0	0.963	8.0	0.961
8.5	0.977	8.5	0.971	8.5	0.967	8.5	0.964	8.5	0.962
9.0	0.977	9.0	0.972	9.0	0.968	9.0	0.965	9.0	0.963
9.5	0.978	9.5	0.973	9.5	0.969	9.5	0.966	9.5	0.964
10.0	0.979	10.0	0.974	10.0	0.970	10.0	0.967	10.0	0.965
10.5	0.979	10.5	0.974	10.5	0.971	10.5	0.968	10.5	0.966
11.0	0.980	11.0	0.975	11.0	0.971	11.0	0.968	11.0	0.967
11.5	0.980	11.5	0.975	11.5	0.972	11.5	0.969	11.5	0.967
12.0	0.981	12.0	0.976	12.0	0.972	12.0	0.970	12.0	0.968
12.5	0.981	12.5	0.976	12.5	0.973	12.5	0.970	12.5	0.969
13.0	0.981	13.0	0.977	13.0	0.974	13.0	0.971	13.0	0.969
13.5	0.982	13.5	0.977	13.5	0.974	13.5	0.971	13.5	0.970
14.0	0.982	14.0	0.978	14.0	0.975	14.0	0.972	14.0	0.970
14.5	0.983	14.5	0.978	14.5	0.975	14.5	0.972	14.5	0.971
15.0	0.983	15.0	0.979	15.0	0.975	15.0	0.973	15.0	0.971

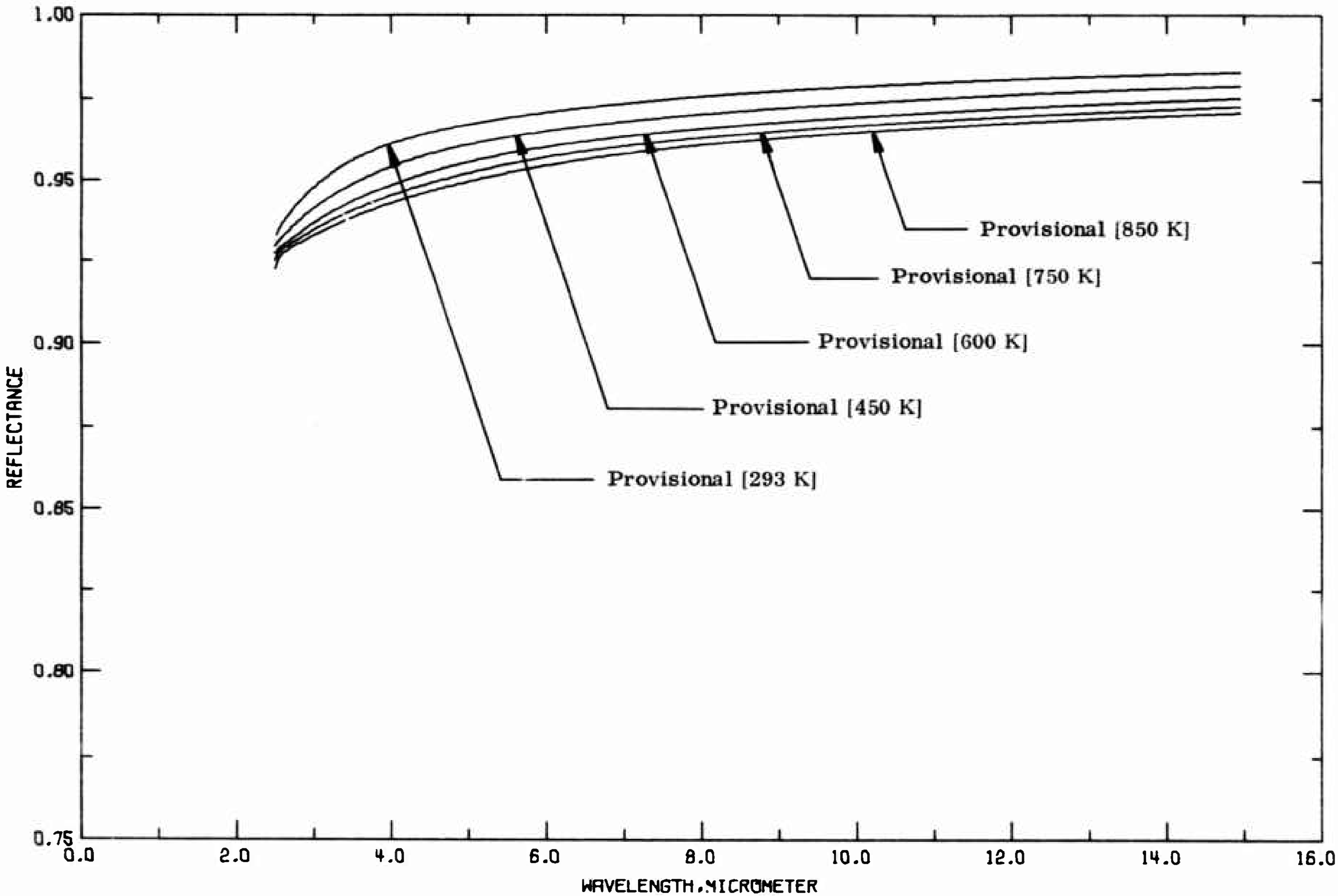


FIGURE 22-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF GRAPHITE FIBER ALUMINUM MATRIX COMPOSITE (WAVELENGTH DEPENDENCE).

d. Normal Spectral Reflectance (Temperature Dependence)

In Table 22-4, the provisional values of the normal spectral reflectance are given with an estimated uncertainty of $\pm 20\%$. The variation of the property as a function of temperature is demonstrated in Figure 22-4. For a given wavelength, the normal spectral reflectance remains as a constant from room temperature up to near the melting point of the material. At higher temperatures our knowledge on this property is lacking. However, it seems that a linear extrapolation of the curve to and above the melting point can be used with uncertainty of no more than $\pm 35\%$.

TABLE 22-4. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF GRAPHITE FIBER ALUMINUM MATRIX COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

T	ρ	T	ρ	T	ρ	T	ρ
MECHANICALLY POLISHED λ = 2.8		MECHANICALLY POLISHED λ = 3.8		MECHANICALLY POLISHED λ = 5.0		MECHANICALLY POLISHED λ = 10.6	
250.0	0.946	250.0	0.962	250.0	0.970	250.0	0.981
293.0	0.943	293.0	0.959	293.0	0.967	293.0	0.979
300.0	0.943	300.0	0.959	300.0	0.967	300.0	0.979
350.0	0.940	350.0	0.956	350.0	0.964	350.0	0.977
400.0	0.938	400.0	0.954	400.0	0.962	400.0	0.976
450.0	0.937	450.0	0.952	450.0	0.960	450.0	0.974
500.0	0.935	500.0	0.950	500.0	0.959	500.0	0.973
550.0	0.934	550.0	0.948	550.0	0.957	550.0	0.972
600.0	0.933	600.0	0.947	600.0	0.956	600.0	0.971
650.0	0.932	650.0	0.945	650.0	0.954	650.0	0.970
700.0	0.932	700.0	0.944	700.0	0.953	700.0	0.969
750.0	0.931	750.0	0.943	750.0	0.952	750.0	0.968
800.0	0.931	800.0	0.942	800.0	0.951	800.0	0.967
850.0	0.930	850.0	0.941	850.0	0.950	850.0	0.966
880.0	0.930	880.0	0.941	880.0	0.949	880.0	0.965

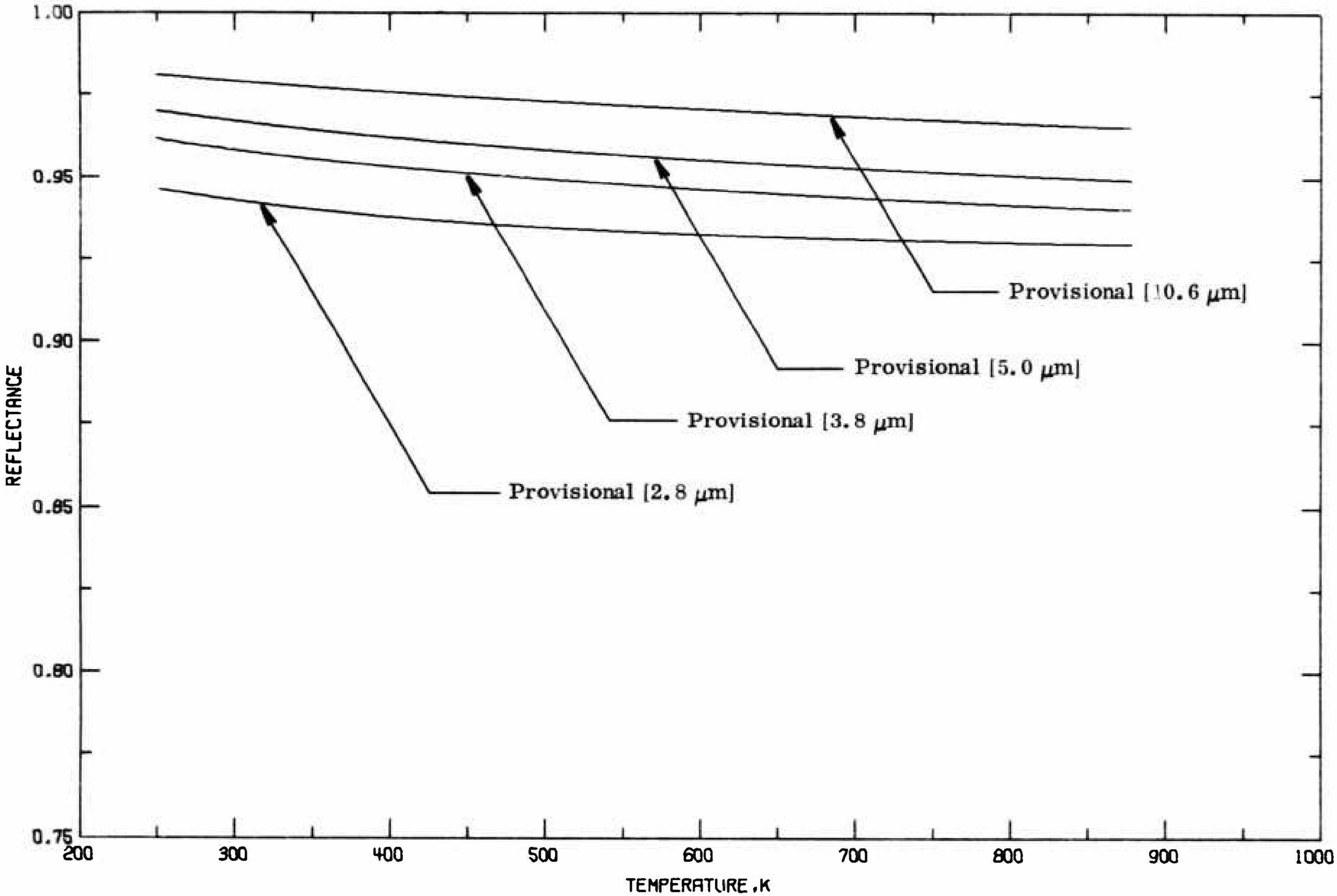


FIGURE 22-4. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF GRAPHITE FIBER ALUMINUM MATRIX COMPOSITE (TEMPERATURE DEPENDENCE).

e. Normal Spectral Absorptance (Wavelength Dependence)

The normal spectral absorptance is obtained according to the Kirchhoff's law, i.e., numerically the absorptance is equal to the emittance. The absorptance varies appreciably for wavelengths lower than 4.0 μm and remains practically unchanged for longer wavelengths. The generated provisional values with ± 25% uncertainty are given in Table 22-5 and plotted in Figure 22-5.

TABLE 22-5. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF GRAPHITE FIBER ALUMINUM MATRIX COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α	λ	α	λ	α	λ	α	λ	α
MECHANICALLY POLISHED T = 293		MECHANICALLY POLISHED T = 450		MECHANICALLY POLISHED T = 600		MECHANICALLY POLISHED T = 750		MECHANICALLY POLISHED T = 850	
2.5	0.067	2.5	0.071	2.5	0.073	2.5	0.075	2.5	0.078
2.8	0.057	2.8	0.063	2.8	0.067	2.8	0.069	2.8	0.070
3.0	0.052	3.0	0.059	3.0	0.063	3.0	0.066	3.0	0.067
3.5	0.044	3.5	0.052	3.5	0.056	3.5	0.060	3.5	0.062
3.8	0.041	3.8	0.048	3.8	0.053	3.8	0.057	3.8	0.059
4.0	0.039	4.0	0.046	4.0	0.051	4.0	0.055	4.0	0.057
4.5	0.035	4.5	0.043	4.5	0.047	4.5	0.051	4.5	0.053
5.0	0.033	5.0	0.040	5.0	0.044	5.0	0.048	5.0	0.050
5.5	0.031	5.5	0.037	5.5	0.042	5.5	0.046	5.5	0.046
6.0	0.029	6.0	0.035	6.0	0.040	6.0	0.043	6.0	0.045
6.5	0.027	6.5	0.034	6.5	0.038	6.5	0.042	6.5	0.044
7.0	0.026	7.0	0.032	7.0	0.037	7.0	0.040	7.0	0.042
7.5	0.025	7.5	0.031	7.5	0.035	7.5	0.039	7.5	0.040
8.0	0.024	8.0	0.030	8.0	0.034	8.0	0.037	8.0	0.039
8.5	0.023	8.5	0.029	8.5	0.033	8.5	0.036	8.5	0.038
9.0	0.023	9.0	0.028	9.0	0.032	9.0	0.035	9.0	0.037
9.5	0.022	9.5	0.027	9.5	0.031	9.5	0.034	9.5	0.036
10.0	0.021	10.0	0.026	10.0	0.030	10.0	0.033	10.0	0.035
10.5	0.021	10.5	0.026	10.5	0.029	10.5	0.032	10.5	0.034
11.0	0.020	11.0	0.025	11.0	0.029	11.0	0.032	11.0	0.033
11.5	0.020	11.5	0.025	11.5	0.028	11.5	0.031	11.5	0.033
12.0	0.019	12.0	0.024	12.0	0.028	12.0	0.030	12.0	0.032
12.5	0.019	12.5	0.024	12.5	0.027	12.5	0.030	12.5	0.031
13.0	0.019	13.0	0.023	13.0	0.026	13.0	0.029	13.0	0.031
13.5	0.018	13.5	0.023	13.5	0.026	13.5	0.029	13.5	0.030
14.0	0.018	14.0	0.022	14.0	0.025	14.0	0.028	14.0	0.030
14.5	0.017	14.5	0.022	14.5	0.025	14.5	0.028	14.5	0.029
15.0	0.017	15.0	0.021	15.0	0.025	15.0	0.027	15.0	0.029

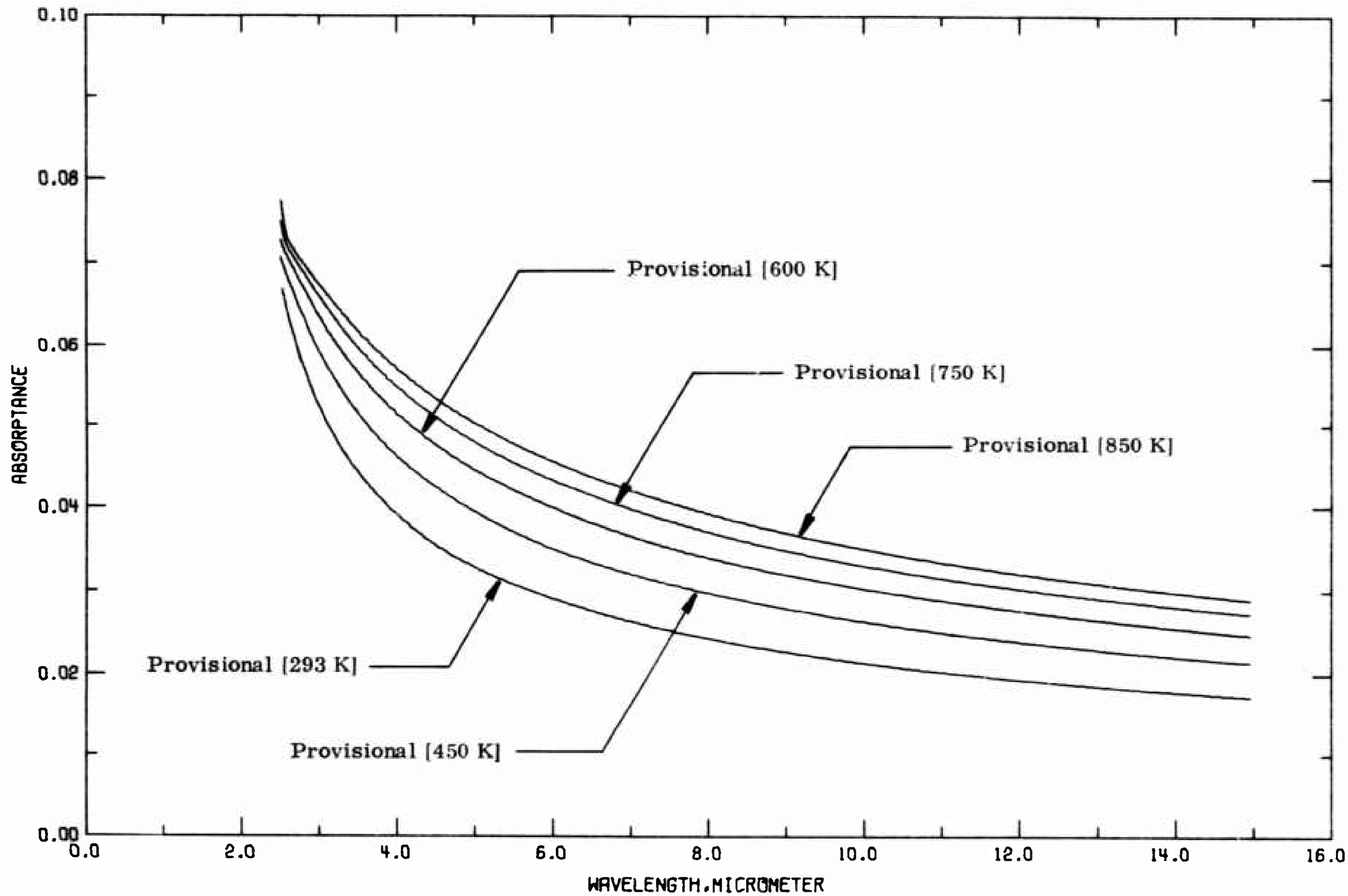


FIGURE 22-5. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF GRAPHITE FIBER ALUMINUM MATRIX COMPOSITE (WAVELENGTH DEPENDENCE).

f. Normal Spectral Absorptance (Temperature Dependence)

The provisional values of the normal spectral absorptance of graphite fiber aluminum matrix composite is given in Table 22-6 and plotted in Figure 22-6. They are numerically equal to the normal spectral emittance. In Figure 22-6, our predicted curves for 5.0 μm and 10.0 μm are higher than experimental values plotted in Figure 20-5. By a careful examination of the measurement information, one sees that the experimental points in Figure 20-5 are for thin films. The absorptance of bulk material is in general higher than that of thin film. An uncertainty of 25% is incorporated to the provisional values so that they can be used for most of the real surfaces.

TABLE 22-6. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF GRAPHITE FIBER ALUMINUM MATRIX COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

T	α	T	α	T	α	T	α
MECHANICALLY POLISHED λ = 2.8		MECHANICALLY POLISHED λ = 3.8		MECHANICALLY POLISHED λ = 5.0		MECHANICALLY POLISHED λ = 10.6	
250.0	0.054	250.0	0.038	250.0	0.030	250.0	0.019
293.0	0.057	293.0	0.041	293.0	0.033	293.0	0.021
300.0	0.057	300.0	0.041	300.0	0.033	300.0	0.021
350.0	0.060	350.0	0.044	350.0	0.036	350.0	0.023
400.0	0.062	400.0	0.046	400.0	0.038	400.0	0.024
450.0	0.063	450.0	0.048	450.0	0.040	450.0	0.026
500.0	0.065	500.0	0.050	500.0	0.041	500.0	0.027
550.0	0.066	550.0	0.052	550.0	0.043	550.0	0.028
600.0	0.067	600.0	0.053	600.0	0.044	600.0	0.029
650.0	0.068	650.0	0.055	650.0	0.046	650.0	0.030
700.0	0.068	700.0	0.056	700.0	0.047	700.0	0.031
750.0	0.069	750.0	0.057	750.0	0.048	750.0	0.032
800.0	0.069	800.0	0.058	800.0	0.049	800.0	0.033
850.0	0.070	850.0	0.059	850.0	0.050	850.0	0.034
880.0	0.070	880.0	0.059	880.0	0.051	880.0	0.035

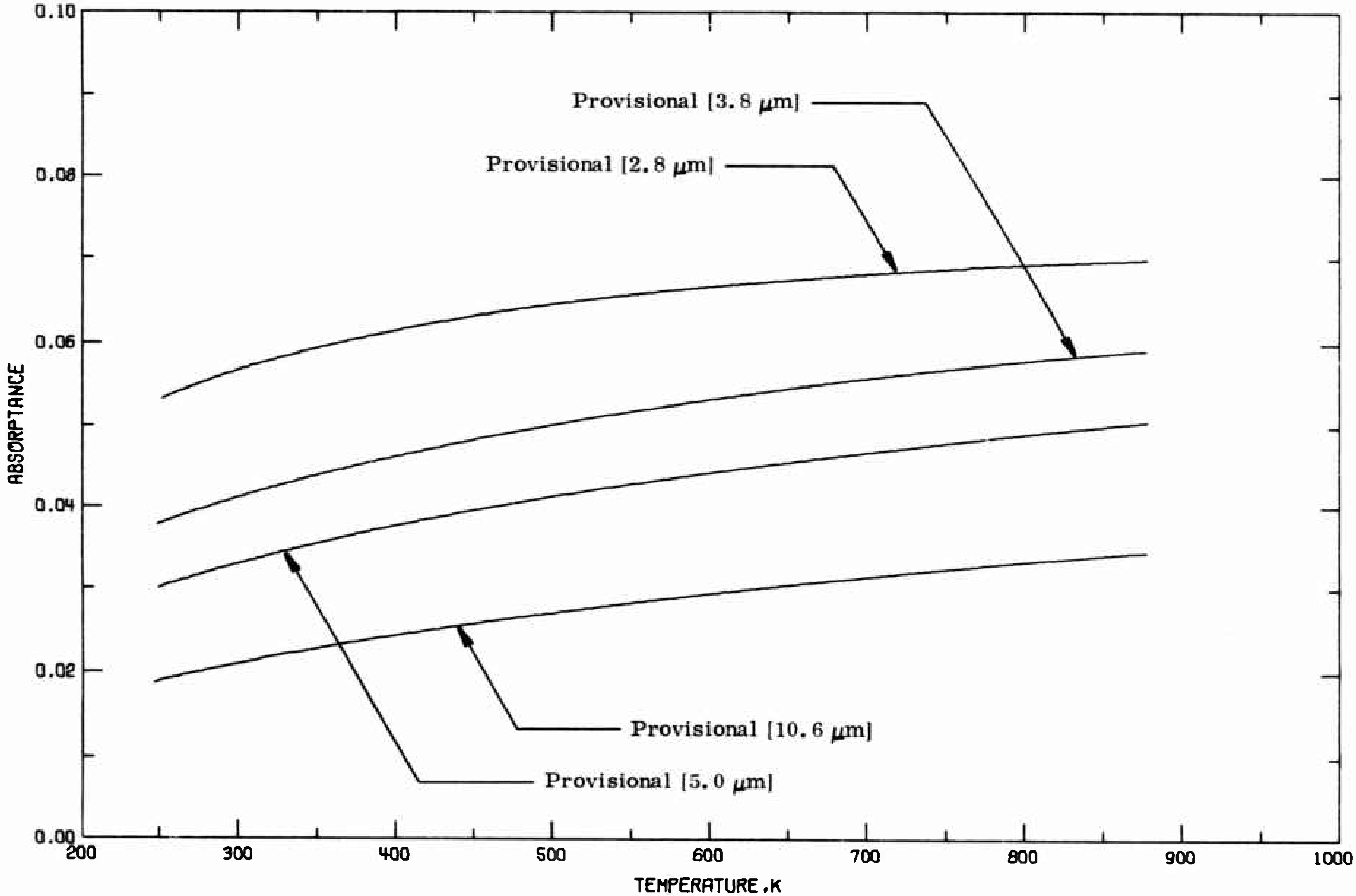


FIGURE 22-6. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF GRAPHITE FIBER ALUMINUM MATRIX COMPOSITE (TEMPERATURE DEPENDENCE).

g. Transmittance

Although it is true that metals in the form of extremely thin films may be transparent for a wide wavelength range, they are opaque if the thickness is greater than several hundred angstroms. Consequently, composites with metal matrix are opaque to visible and infrared radiation because in general applications they are not used as extremely thin films. This leads to the conclusion that as an aircraft/spacecraft structural material, this composite is opaque and its transmittance is zero.

4.23. Boron Fiber Epoxy Composite

This composite material consists usually of continuous boron filaments surrounded by a matrix of epoxy resin. It is usually produced in tape form so it can be used in further fabrication of specialized materials.

The boron filaments, as currently produced, are formed by vapor deposition of boron on a fine tungsten wire substrate within a reactor. Exposure of the tungsten substrate to the high-temperature boron trichloride reactor environment results in a filament consisting of a boron sheath on a tungsten boride core. Other means of producing boron filaments are currently being investigated which would eliminate the tungsten substrate.

The organic matrix resins most commonly used with boron filaments are modified epoxy resins available as commercial formulations developed specifically for this purpose. Other organic resins used include polyamides and phenolics. However, the state of the art with these resins is less advanced than for the epoxy materials.

The normal service temperature range of the boron fiber epoxy composite is dependent on the type of epoxy resin being used as a matrix. This range is nominally 220 K, where the epoxy becomes very brittle, to 450 K. Epoxy resin decomposes around 590 K.

The boron fiber epoxy is fabricated primarily for aircraft constructions, much of its mechanical and thermal properties are studied. As a result, a large amount of experimental data are made available. However, with regard to the thermal radiative properties of the composite, it is quite discouraging. Only one set of systematic experimentally determined data on the normal spectral reflectance is all that can be uncovered by our open literature search. This leaves us no choice but to use it as the basis for the estimation of the most probable values of the radiative properties for boron fiber epoxy composite.

The fact that the composite material is made by bonding boron fibers in a matrix of epoxy resin implies that epoxy is the material which predominately contributes to the thermal radiative properties of the composite material. The other component, the boron fiber, plays minor role. Indeed, by comparing the shapes of the normal spectral reflectance curves (Figure 23-4 in this subsection and Figures 24-4 and 25-4 in subsections 4.24 and 4.25 respectively) we can see the spectral band patterns of the three epoxy composite materials (boron fiber epoxy composite, glass fiber epoxy composite and graphite fiber epoxy composite) are similar.

Reflectance of epoxy is generally fairly low, about 10%, for wavelengths longer than 2.5 μm. Also, it does not change appreciably as the material is heated up and goes decomposition phase and into the char region [A00004]. In other words, the radiative properties of epoxy are independent of temperature.

For epoxy composite materials, the following two relations are commonly used as good approximations:

$$\alpha(0,\lambda) = 1 - \rho(0, 2\pi, \lambda);$$

$$\epsilon(0,\lambda) = \alpha(0,\lambda),$$

because of opaqueness of the materials.

According to the facts discussed above, we are in a position to estimate the following six subproperties for boron fiber epoxy composite based on the single available set of reflectance data:

Normal spectral emittance (wavelength dependence)
Normal spectral emittance (temperature dependence)
Normal spectral reflectance (wavelength dependence)
Normal spectral reflectance (temperature dependence)
Normal spectral absorptance (wavelength dependence)
Normal spectral absorptance (temperature dependence)

a. Normal Spectral Emittance (Wavelength Dependence)

Provisonal values of the normal spectral emittance of slightly grit-blasted boron fiber epoxy composite are obtained from the analyzed result of reflectance by using the relation $\alpha(0,\lambda) = 1 - \rho(0, 2\pi, \lambda)$ and Kirchhoff's law. Such conversion is frequently used for the materials whose reflectance is known [A00004]. The provisional values, listed in Table 23-1 and plotted in Figure 23-1, are in general very close to unity. For rough uses, a value of 0.95 can be safely used because the uncertainty of the provisional values is ± 20%.

TABLE 23-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF BORON FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

λ	ϵ
LIGHTLY GRIT-BLASTED T = 293	
2.5	0.934
2.8	0.955
3.0	0.962
3.5	0.955
3.8	0.944
4.0	0.942
4.5	0.940
5.0	0.940
5.5	0.948
6.0	0.965
6.5	0.967
7.0	0.967
7.5	0.967
8.0	0.966
8.5	0.962
9.0	0.959
9.5	0.958
10.0	0.956
10.5	0.956
10.6	0.956
11.0	0.956
11.5	0.956
12.0	0.956
12.5	0.956
13.0	0.956
13.5	0.956
14.0	0.957
14.5	0.961
15.0	0.973

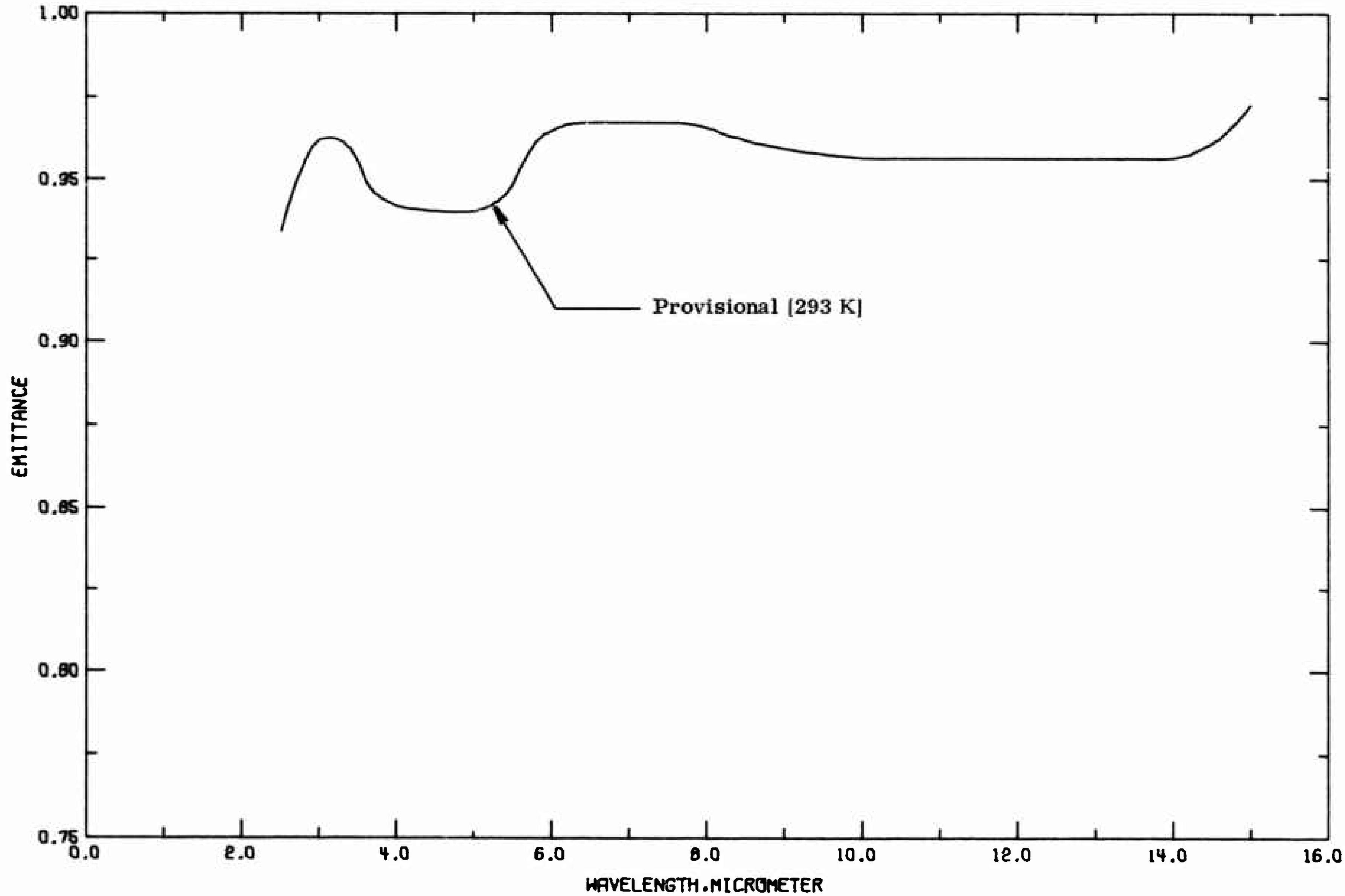


FIGURE 23-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF BORON FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE).

b. Normal Spectral Emittance (Temperature Dependence)

The normal spectral emittance as a function of temperature is given in Table 23-2 and plotted in Figure 23-2. The generated values are considered as provisional with 20% uncertainty. Here, we present the property values as a constant for a given wavelength because it has been observed in epoxy composites that the radiative properties do not change appreciably with temperature [A00002]. With 20% uncertainty, the provisional values can be safely used for most of the true surfaces.

TABLE 23-2. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF BORON FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ	T	ϵ	T	ϵ	T	ϵ
LIGHTLY GRIT-BLASTED λ = 2.8		LIGHTLY GRIT-BLASTED λ = 3.8		LIGHTLY GRIT-BLASTED λ = 5.0		LIGHTLY GRIT-BLASTED λ = 10.6	
250.0	0.955	250.0	0.944	250.0	0.940	250.0	0.956
300.0	0.955	300.0	0.944	300.0	0.940	300.0	0.956
350.0	0.955	350.0	0.944	350.0	0.940	350.0	0.956
400.0	0.955	400.0	0.944	400.0	0.940	400.0	0.956
450.0	0.955	450.0	0.944	450.0	0.940	450.0	0.956
500.0	0.955	500.0	0.944	500.0	0.940	500.0	0.956

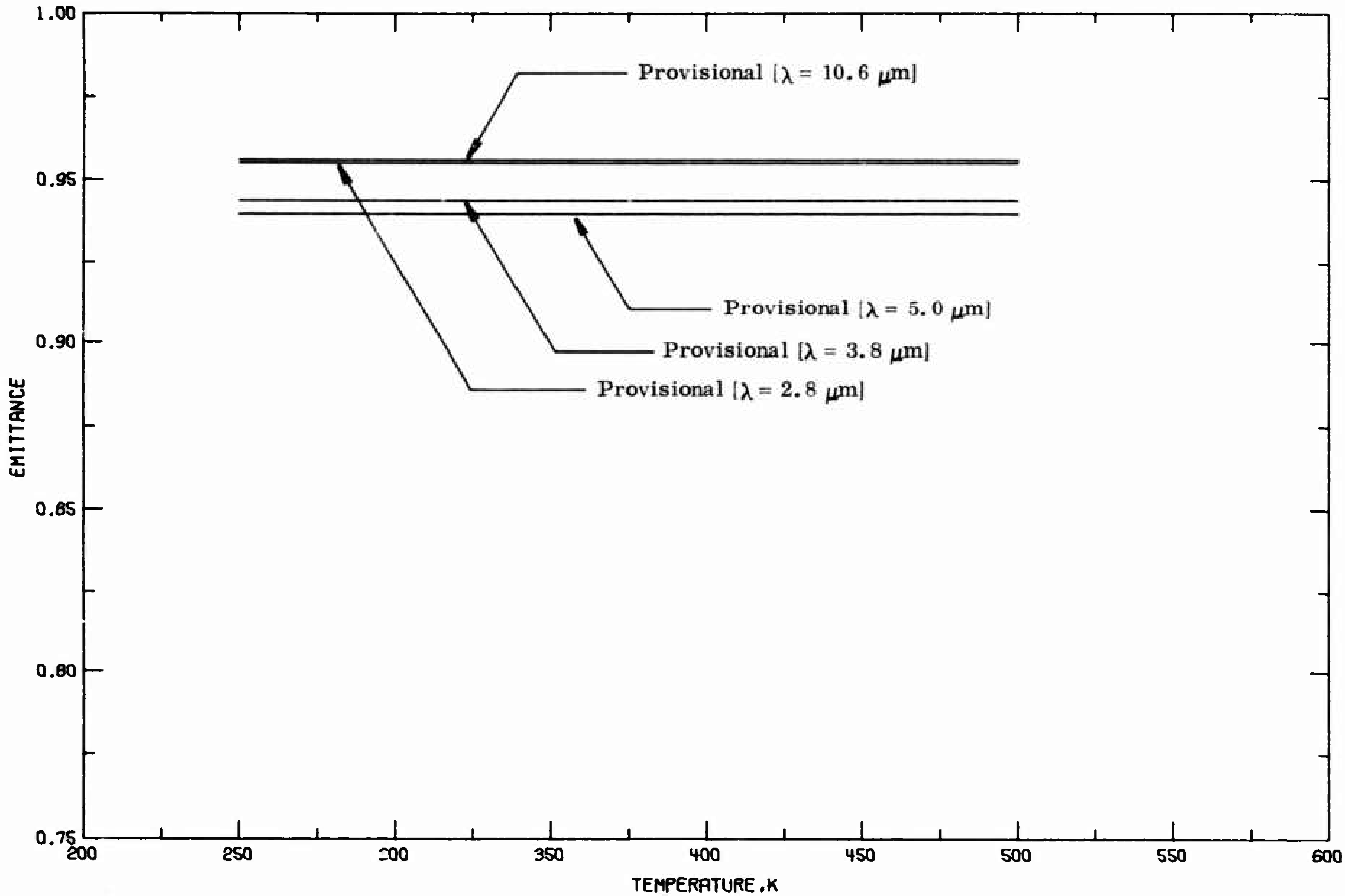


FIGURE 23-2. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF BORON FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE).

c. Normal Spectral Reflectance (Wavelength Dependence)

As given in Table 23-3 and plotted in Figure 23-3, the provisional values of boron fiber epoxy composite are obtained by reading off from a curve smoothed out from the only available set of data shown in Figure 23-4. It shows a quite complex spectral distribution of energy reflected from the composite material. Because of scantiness of the available data and spectral complexity, no attempt was made to carry out analytical calculations but the smoothing technique. An estimated uncertainty of 25% is given to the provisional values which are believed to be reasonable for most of the real surfaces.

TABLE 23-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF BORON FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ
LIGHTLY GRIT-BLASTED T = 293	
2.5	0.066
2.8	0.045
3.0	0.036
3.5	0.045
3.8	0.056
4.0	0.058
4.5	0.060
5.0	0.060
5.5	0.052
6.0	0.035
6.5	0.033
7.0	0.033
7.5	0.033
8.0	0.034
8.5	0.038
9.0	0.041
9.5	0.042
10.0	0.044
10.5	0.044
10.6	0.044
11.0	0.044
11.5	0.044
12.0	0.044
12.5	0.044
13.0	0.044
13.5	0.044
14.0	0.043
14.5	0.039
15.0	0.027

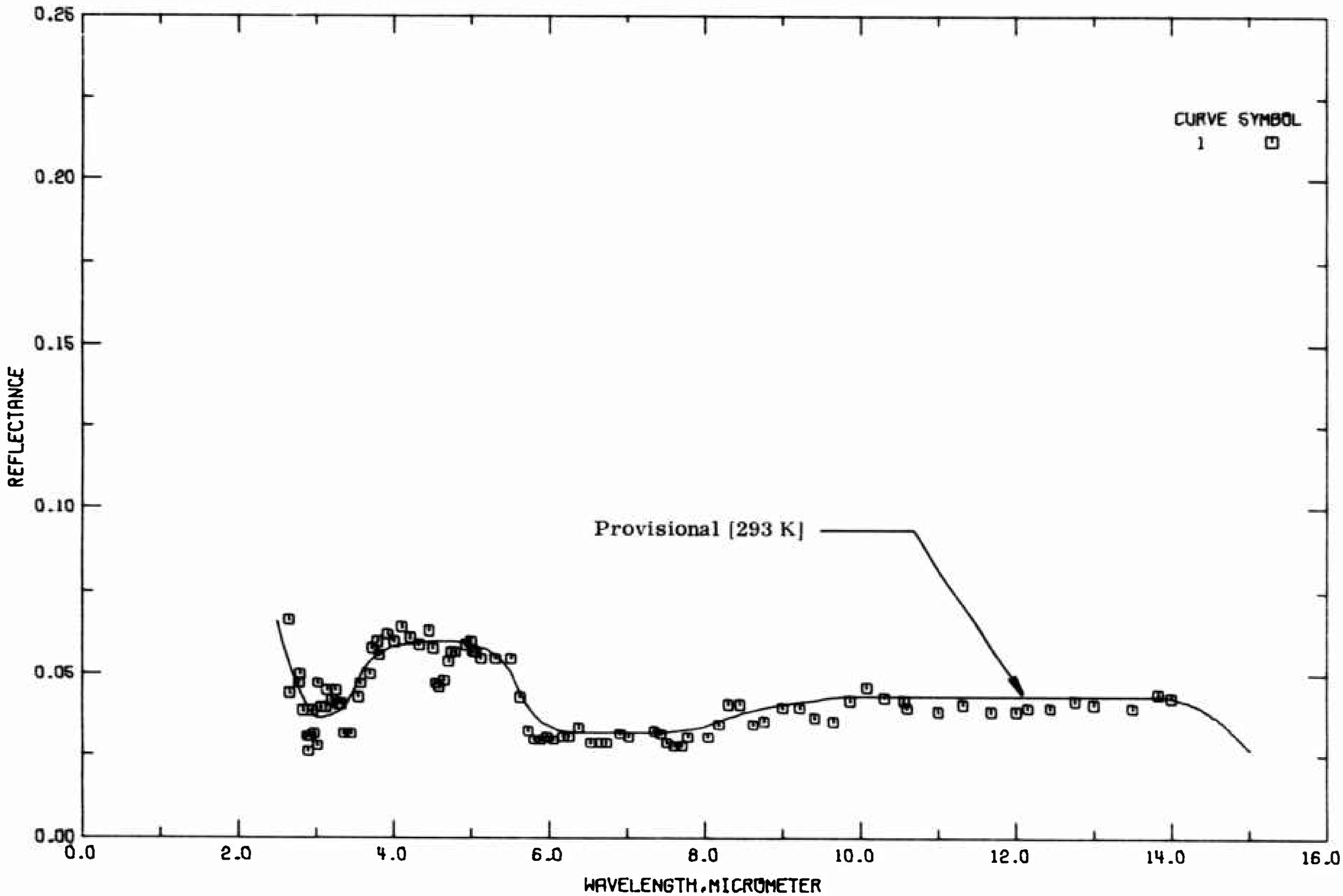


FIGURE 23-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF BORON FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE).

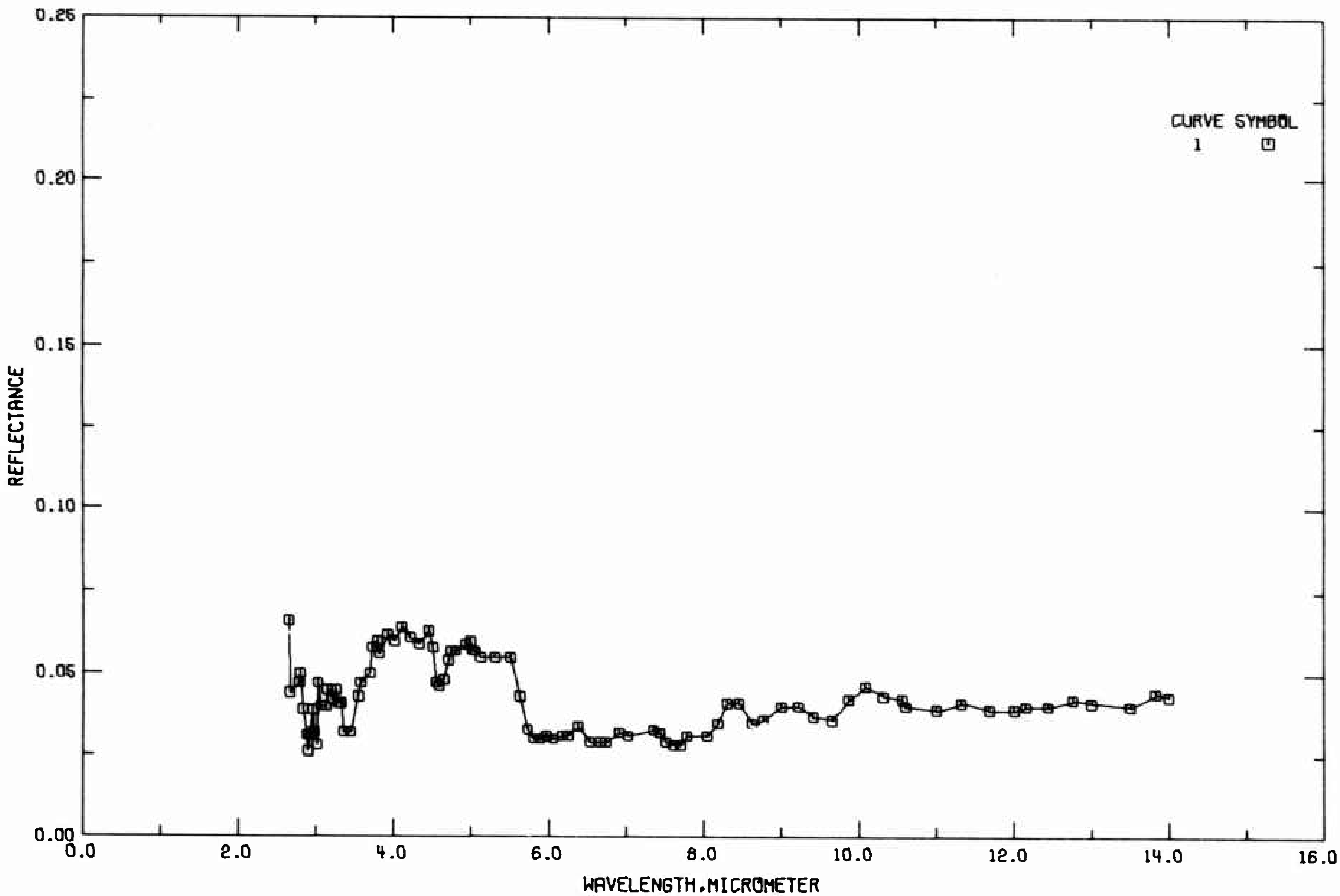


FIGURE 23-4. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF BORON FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE).

TABLE 23-4. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF BORON FIBER EPOXY COMPOSITE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00001	Grimm, T.C.	1972	2.0-14.7	293		Bare surface specimen; 2.54 cm square; lightly grit-blasted; prepared by the Organic Chemistry Laboratory in the company where the author worked; measurements made with a Dunn Associates ellipsoidal mirror reflectometer; data extracted from a figure; relative reflectance reported; multiplied by 0.95 to convert to absolute values (gold reference mirror used); $\theta = 15°$, $\omega' = 2\pi$.

TABLE 23-5. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF BORON FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ	λ	ρ	λ	ρ
CURVE 1		CURVE 1 (CONT.)		CURVE 1 (CONT.)	
T = 295.					
		4.90	0.057	10.31	0.043
2.66	0.066	4.93	0.059	10.56	0.042
2.67	0.044	5.00	0.060	10.60	0.040
2.79	0.047	5.02	0.057	11.00	0.039
2.80	0.050	5.06	0.057	11.32	0.041
2.84	0.039	5.12	0.055	11.68	0.039
2.89	0.031	5.31	0.055	12.00	0.039
2.90	0.026	5.51	0.055	12.15	0.040
2.93	0.031	5.63	0.043	12.44	0.040
2.96	0.039	5.73	0.033	12.76	0.042
2.98	0.032	5.81	0.030	13.00	0.041
3.02	0.028	5.89	0.030	13.50	0.040
3.03	0.047	5.97	0.031	13.83	0.044
3.07	0.040	6.05	0.030	14.00	0.043
3.13	0.040	6.18	0.031	14.26	0.040
3.15	0.045	6.25	0.031	14.51	0.033
3.21	0.042	6.38	0.034	14.69	0.030
3.26	0.045	6.53	0.029		
3.29	0.041	6.67	0.029		
3.33	0.041	6.73	0.029		
3.36	0.032	6.91	0.032		
3.45	0.032	7.02	0.031		
3.55	0.043	7.35	0.033		
3.58	0.047	7.43	0.032		
3.70	0.050	7.51	0.029		
3.73	0.058	7.61	0.028		
3.80	0.060	7.70	0.028		
3.82	0.056	7.78	0.031		
3.93	0.062	8.04	0.031		
4.01	0.060	8.18	0.035		
4.11	0.064	8.30	0.041		
4.22	0.061	8.45	0.041		
4.33	0.059	8.62	0.035		
4.46	0.063	8.76	0.036		
4.51	0.058	9.00	0.040		
4.55	0.047	9.22	0.040		
4.59	0.046	9.41	0.037		
4.65	0.048	9.65	0.036		
4.71	0.054	9.87	0.042		
4.75	0.057	10.08	0.046		

d. Normal Spectral Reflectance (Temperature Dependence)

In Table 23-6, the provisional values of the normal spectral reflectance are given with estimated uncertainties of $\pm 25\%$. The variation of the property as a function of temperature is demonstrated in Figure 23-5. For a given wavelength, the normal spectral reflectance remains as a constant from room temperature up to the char region of epoxy. The independency of the reflectance of epoxy composite with temperature has been observed experimentally [A00002]. The reported provisional values are believed to be reasonable in most of the real situation.

TABLE 23-6. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF BORON FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

T	ρ	T	ρ	T	ρ	T	ρ
LIGHTLY GRIT-BLASTED λ = 2.8		LIGHTLY GRIT-BLASTED λ = 3.8		LIGHTLY GRIT-BLASTED λ = 5.0		LIGHTLY GRIT-BLASTED λ = 10.6	
250.0	0.045	250.0	0.056	250.0	0.060	250.0	0.044
300.0	0.045	300.0	0.056	300.0	0.060	300.0	0.044
350.0	0.045	350.0	0.056	350.0	0.060	350.0	0.044
400.0	0.045	400.0	0.056	400.0	0.060	400.0	0.044
450.0	0.045	450.0	0.056	450.0	0.060	450.0	0.044
500.0	0.045	500.0	0.056	500.0	0.060	500.0	0.044

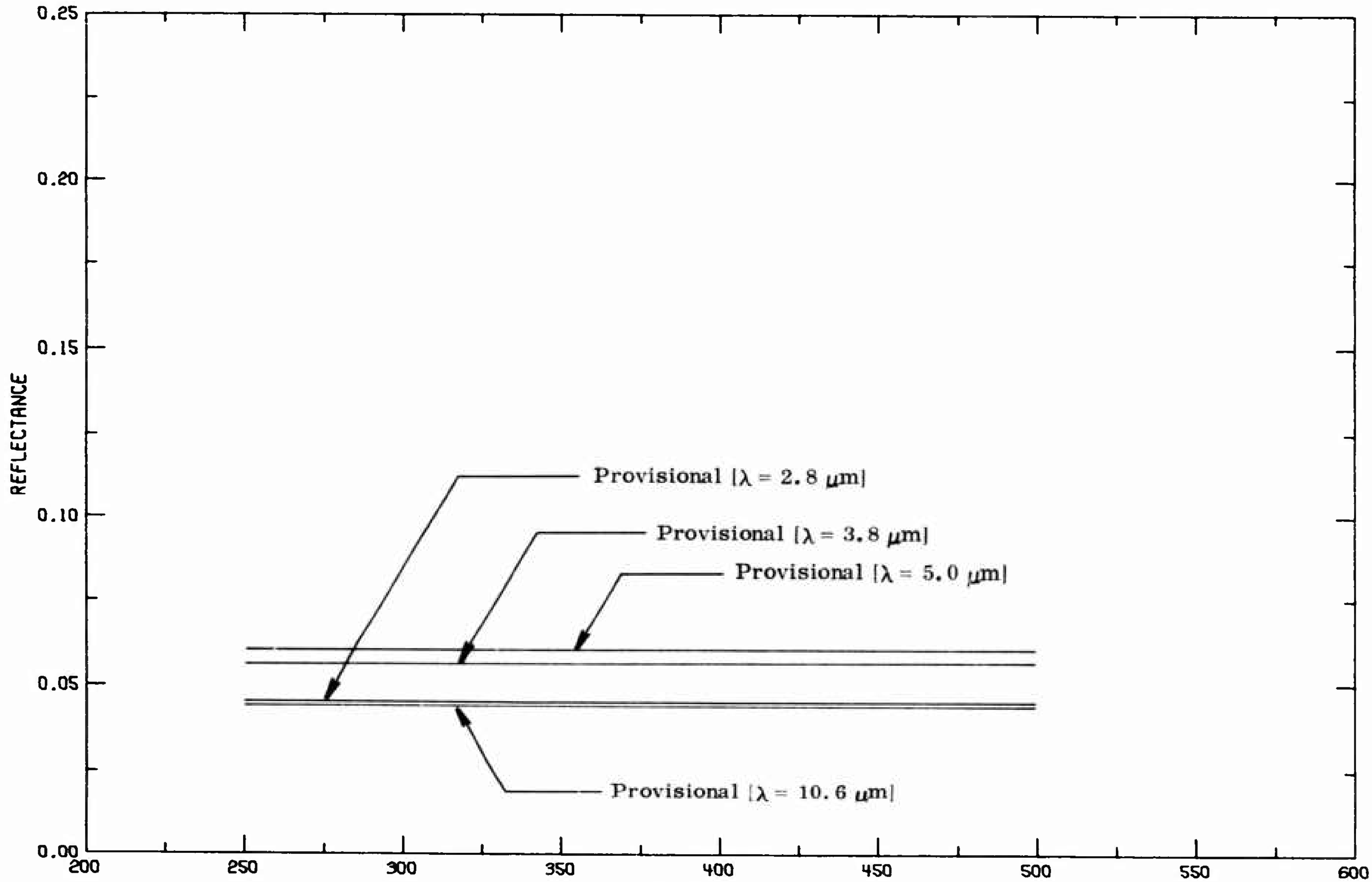


FIGURE 23-5. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF BORON FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE).

e. Normal Spectral Absorptance (Wavelength Dependence)

The normal spectral absorptance is obtained according to the Kirchhoff's law, i.e., numerically the absorptance is equal to the emittance. As a result, Table 23-7 and Figure 23-6 appear the same as Table 23-1 and Figure 23-1, as well as the estimated uncertainties ($\pm$20%).

TABLE 23-7. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF BORON FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α)

λ	α
LIGHTLY GRIT-BLASTED T = 293	
2.5	0.934
2.8	0.955
3.0	0.962
3.5	0.955
3.8	0.944
4.0	0.942
4.5	0.940
5.0	0.940
5.5	0.948
6.0	0.955
6.5	0.967
7.0	0.967
7.5	0.967
8.0	0.966
8.5	0.962
9.0	0.959
9.5	0.958
10.0	0.956
10.5	0.956
10.6	0.956
11.0	0.956
11.5	0.956
12.0	0.956
12.5	0.956
13.0	0.956
13.5	0.956
14.0	0.957
14.5	0.961
15.0	0.973

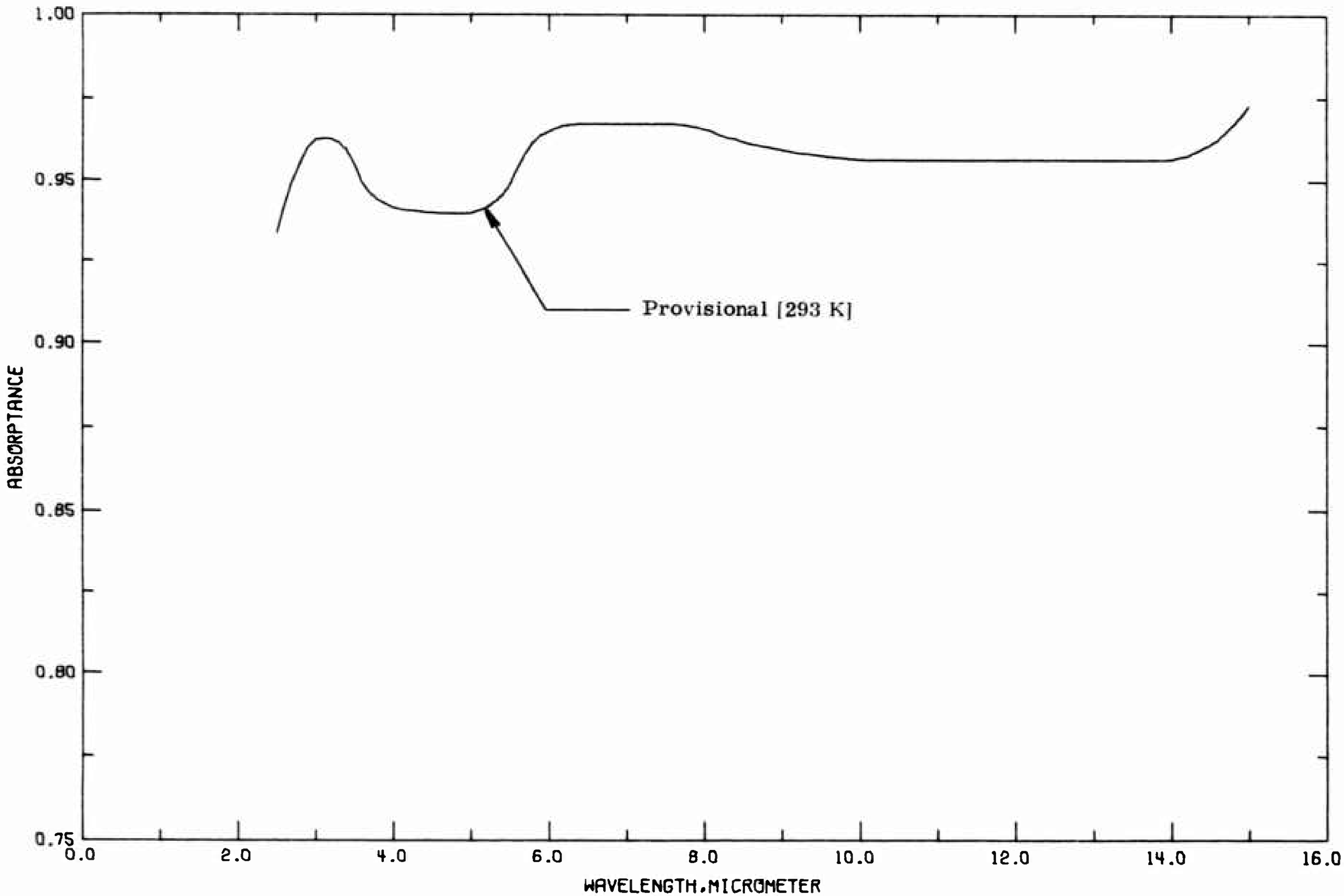


FIGURE 23-6. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF BORON FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE).

f. Normal Spectral Absorptance (Temperature Dependence)

The normal spectral absorptance as a function of temperature is given in Table 23-8 and plotted in Figure 23-7. The generated values are considered as provisional with 20% uncertainty. Here, we present the property values as constant for a given wavelength because it has been observed in epoxy composites that the radiative properties do not change appreciably with temperature [A00002]. With 20% uncertainty, the provisional values can be safely used for most of the true surfaces.

TABLE 23-8. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF BORON FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

T	α	T	α	T	α	T	α
LIGHTLY GRIT-BLASTED λ = 2.8		LIGHTLY GRIT-BLASTED λ = 3.8		LIGHTLY GRIT-BLASTED λ = 5.0		LIGHTLY GRIT-BLASTED λ = 10.6	
250.0	0.955	250.0	0.944	250.0	0.940	250.0	0.956
300.0	0.955	300.0	0.944	300.0	0.940	300.0	0.956
350.0	0.955	350.0	0.944	350.0	0.940	350.0	0.956
400.0	0.955	400.0	0.944	400.0	0.940	400.0	0.956
450.0	0.955	450.0	0.944	450.0	0.940	450.0	0.956
500.0	0.955	500.0	0.944	500.0	0.940	500.0	0.956

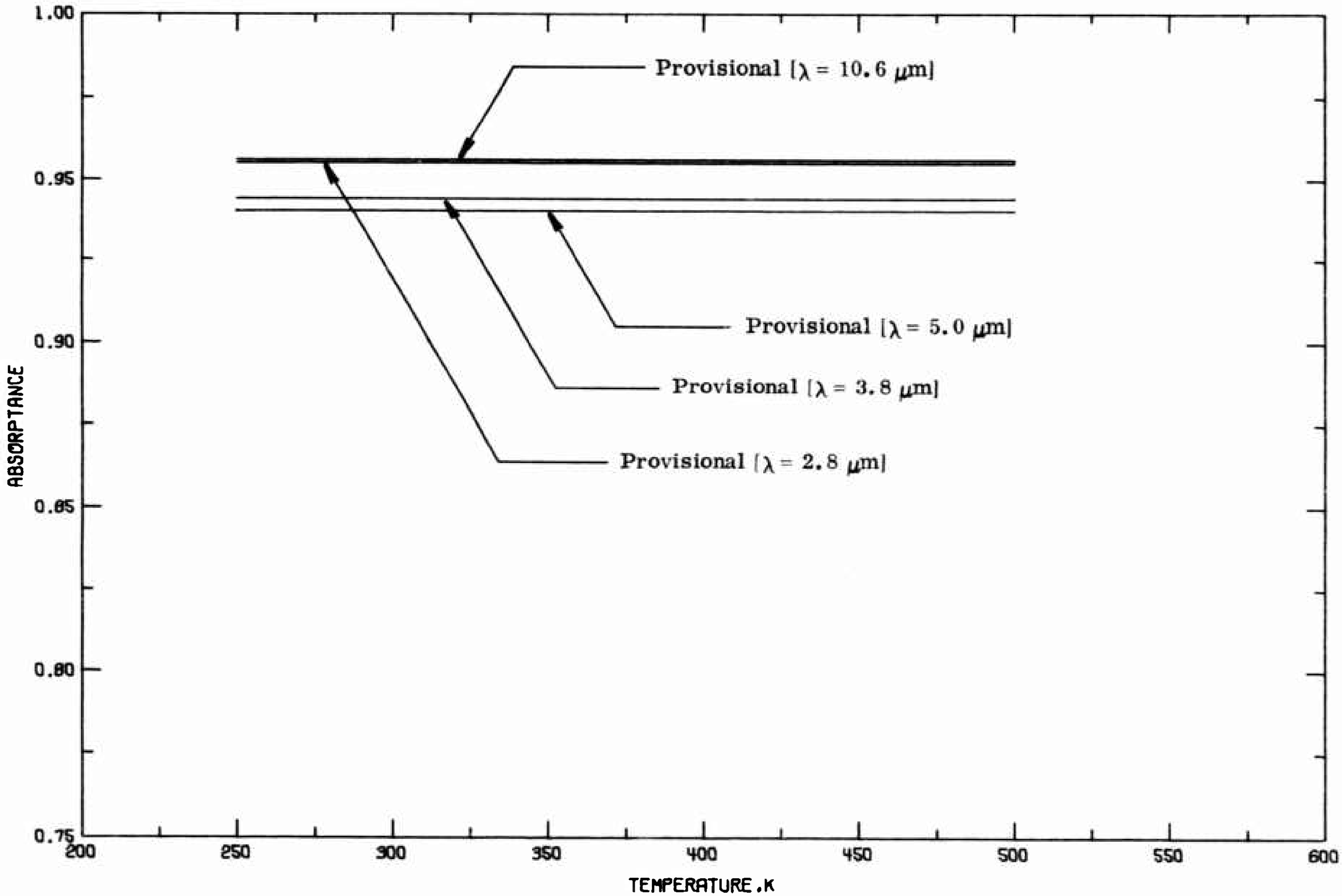


FIGURE 23-7. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF BORON FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE).

4.24. Glass Fiber Epoxy Composite

A small amount of the exterior area of the aircraft is composed of nonmetallics. These nonmetallics consist chiefly various glass fiber reinforced plastics, and epoxy composites, etc.

Composite materials have received great interest in the last decade because they provide unusual combinations of properties which cannot be obtained with any single, homogeneous substance. In aircraft and missile design, they have provided structural materials of very high strength and elastic modulus which also have low densities.

Among nonmetallic composites, the glass/epoxy composites are the most commonly used. The glass fiber epoxy composite consists usually of fine glass fibers surrounded by a matrix of epoxy resin. The other alternative form commonly used is the glass fabric reinforced plastics with epoxy surfacer.

Modified epoxy resins developed specifically for use in composites with glass fiber are available commercially. These are thermosetting resins used for low pressure laminating which normally cannot be used in continuous service above about 450 K although intermittent service at temperature up to 490 K is possible. Many of the various epoxy resins used as matrix constituents of composites are proprietory formulations whose exact chemical compositions are not available.

Although the mechanical and thermal properties of glass/epoxy composites are well studied, the thermal radiative properties are unattended. As a result, only one set of experimentally determined data on the normal spectral reflectance is all that can be found by our open literature search. This leaves us no choice but to use it as the basis for the estimation of the most probable values of the radiative properties for glass fiber epoxy composite.

The fact that the composite material is made by bonding the fibers in a matrix of epoxy resin implies that epoxy is the material which predominately contributes to the thermal radiative properties of the composite material. The other component, the fiber material, plays a minor role. Indeed, by comparing the shapes of the normal spectral reflectance curves (Figure 24-4 in this subsection and Figures 23-4 and 25-4 in subsections 4.23 and 4.25 respectively) we can see the spectral band patterns of the three epoxy composite materials (boron fiber epoxy composite, glass fiber epoxy composite and graphite fiber epoxy composite) are similar.

Reflectance of epoxy is generally fairly low, about 10%, for wavelengths longer than 2.5 μm. Also, it does not change appreciably as the material is heated up and goes

decomposition phase and into the char region [A00004]. In other words, the radiative properties of epoxy are independent of temperature.

For epoxy composite materials, the following two relations are commonly used [A00004] as good approximations:

$$\alpha(0,\lambda) = 1 - \rho(0,2\pi,\lambda);$$

$$\epsilon(0,\lambda) = \alpha(0,\lambda),$$

because of opaqueness of the materials.

According to the facts discussed above, we are in a position to estimate the following six subproperties for glass fiber epoxy composite based on the single available set of reflectance data:

Normal spectral emittance (wavelength dependence)
Normal spectral emittance (temperature dependence)
Normal spectral reflectance (wavelength dependence)
Normal spectral reflectance (temperature dependence)
Normal spectral absorptance (wavelength dependence)
Normal spectral absorptance (temperature dependence)

a. Normal Spectral Emittance (Wavelength Dependence)

Provisional values of the normal spectral emittance of slightly grit-blasted glass fiber epoxy composite are obtained from the analyzed result of reflectance by using the relation $\alpha(0,\lambda) = 1 - \rho(0,2\pi,\lambda)$ and Kirchhoff's law. Such conversion is frequently used for the materials whose reflectance is known [A00004]. The provisional values, listed in Table 24-1 and plotted in Figure 24-1, are in general very close to unity. For rough uses, a value of 0.95 can be safely used because the uncertainty of the provisional values is $\pm 20\%$.

TABLE 24-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF GLASS FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
LIGHTLY GRIT-BLASTED T = 293	
2.8	0.926
3.0	0.343
3.5	0.954
3.8	0.943
4.0	0.339
4.5	0.937
5.0	0.940
5.5	0.954
6.0	0.971
6.5	0.976
7.0	0.976
7.5	0.976
8.0	0.976
8.5	0.976
9.0	0.375
9.5	0.964
10.0	0.957
10.5	0.964
10.6	0.966
11.0	0.970
11.5	0.974
12.0	0.977
12.5	0.980
13.0	0.980
13.5	0.975
14.0	0.970
14.5	0.966
15.0	0.963

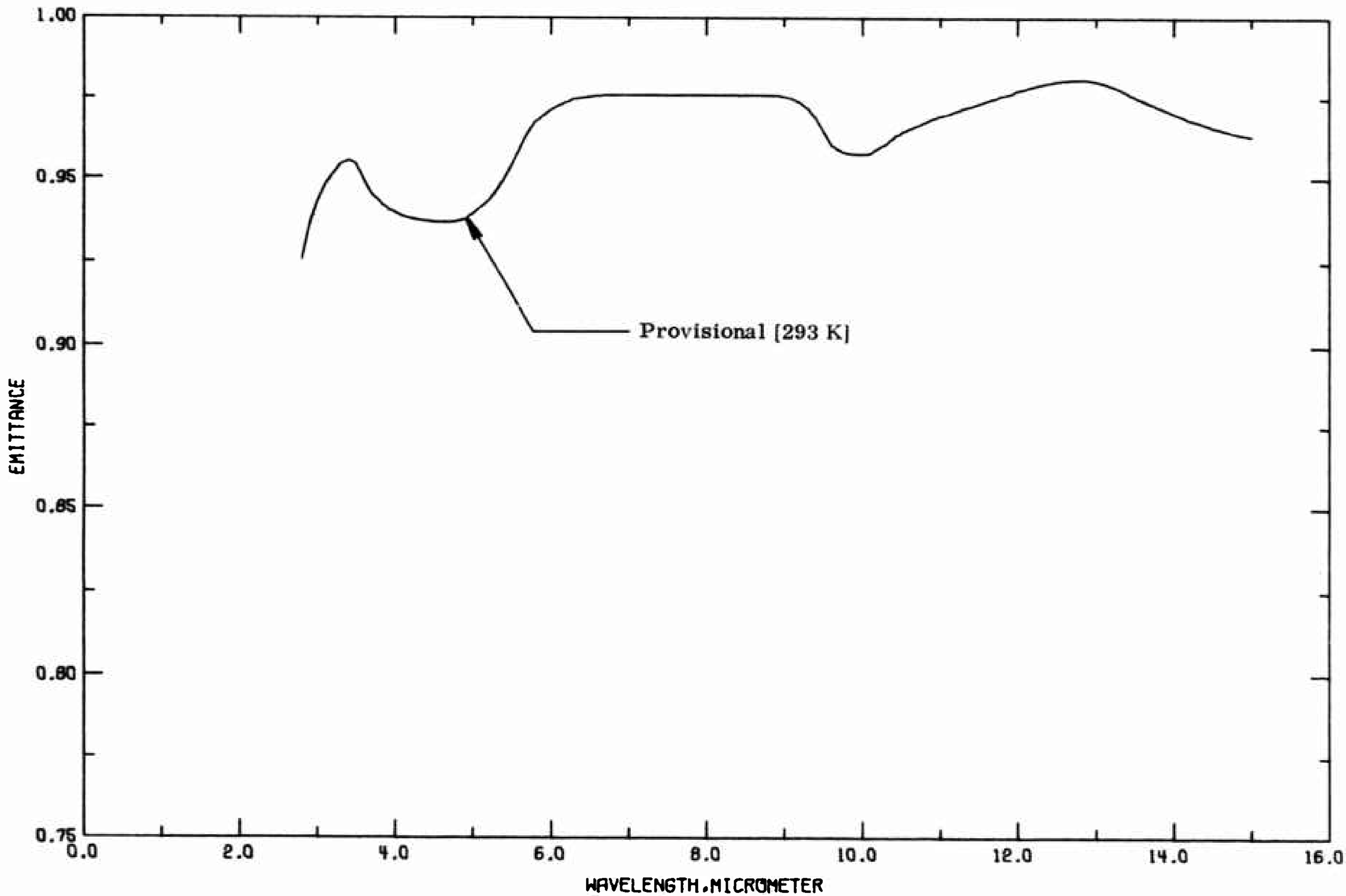


FIGURE 24-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF GLASS FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE).

b. Normal Spectral Emittance (Temperature Dependence)

The normal spectral emittance as a function of temperature is given in Table 24-2 and plotted in Figure 24-2. The generated values are considered as provisional with 20% uncertainty. Here, we present the property values as a constant for a given wavelength because it has been observed in epoxy composites that the radiative properties do not change appreciably with temperature [A00002]. With 20% uncertainty, the provisional values can be safely used for most of the true surfaces.

TABLE 24-2. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF GLASS FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ	T	ϵ	T	ϵ	T	ϵ
LIGHTLY GRIT-BLASTED λ = 2.8		LIGHTLY GRIT-BLASTED λ = 3.8		LIGHTLY GRIT-BLASTED λ = 5.0		LIGHTLY GRIT-BLASTED λ = 10.6	
250.0	0.926	250.0	0.943	250.0	0.940	250.0	0.966
300.0	0.926	300.0	0.943	300.0	0.940	300.0	0.966
350.0	0.926	350.0	0.943	350.0	0.940	350.0	0.966
400.0	0.926	400.0	0.943	400.0	0.940	400.0	0.966
450.0	0.926	450.0	0.943	450.0	0.940	450.0	0.966
500.0	0.926	500.0	0.943	500.0	0.940	500.0	0.966

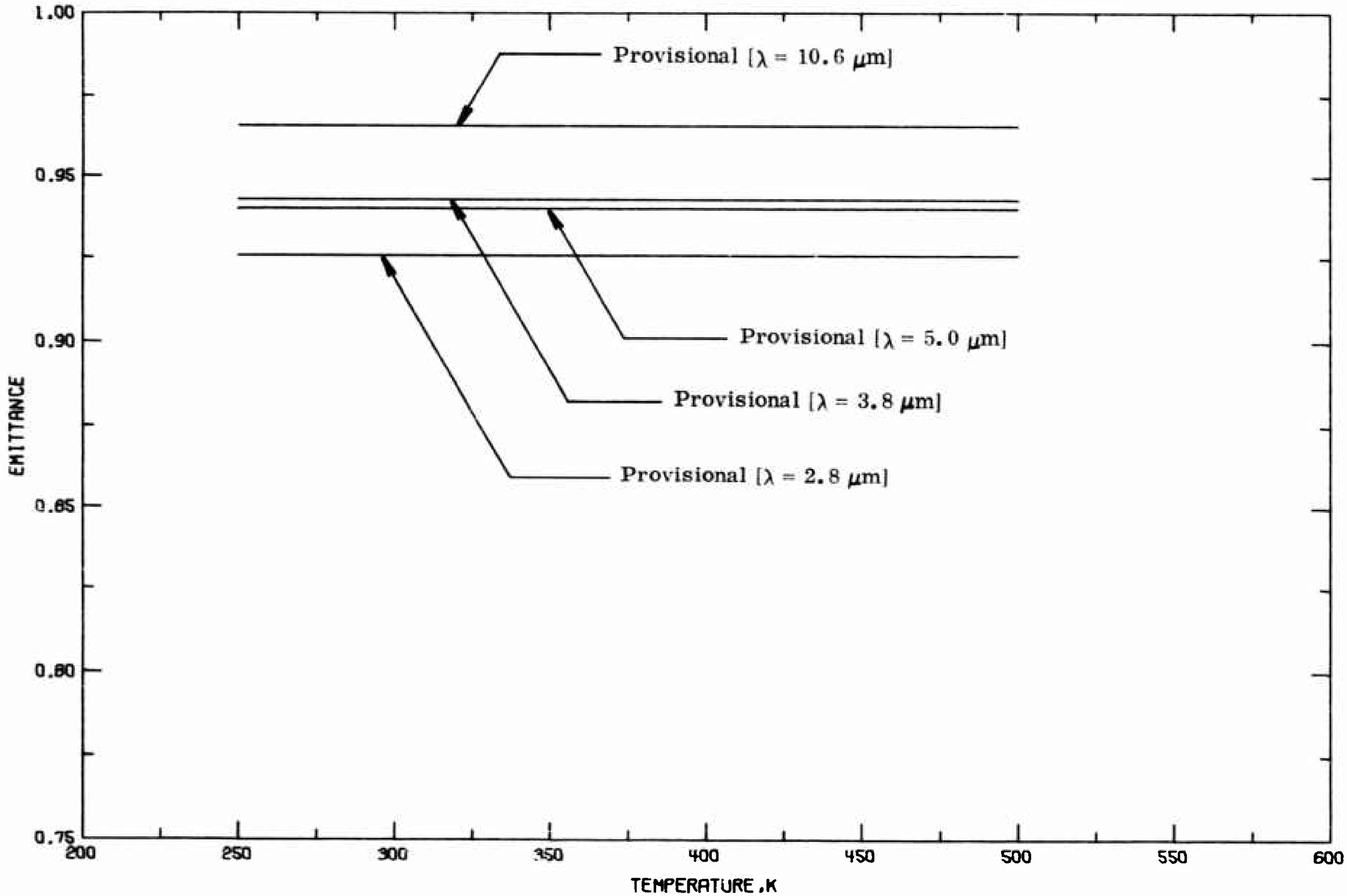


FIGURE 24-2. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF GLASS FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE).

c. Normal Spectral Reflectance (Wavelength Dependence)

As given in Table 24-3 and plotted in Figure 24-3, the provisional values of glass fiber epoxy composite are obtained by reading off from a curve smoothed out from the only available set of data shown in Figure 24-4. It shows a quite complex spectral distribution of energy reflected from the composite material. Because of scantiness of the available data and spectral complexity, no attempt was made to carry out analytical calculations but the smoothing technique. An estimated uncertainty of 25% is given to the provisional values which are believed to be reasonable for most of the real surfaces.

TABLE 24-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF GLASS FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ
LIGHTLY GRIT-BLASTED T = 293	
2.8	0.074
3.0	0.057
3.5	0.046
3.8	0.057
4.0	0.061
4.5	0.063
5.0	0.060
5.5	0.046
6.0	0.029
6.5	0.024
7.0	0.024
7.5	0.024
8.0	0.024
8.5	0.024
9.0	0.025
9.5	0.036
10.0	0.043
10.5	0.036
10.6	0.034
11.0	0.030
11.5	0.026
12.0	0.023
12.5	0.020
13.0	0.020
13.5	0.025
14.0	0.030
14.5	0.034
15.0	0.037

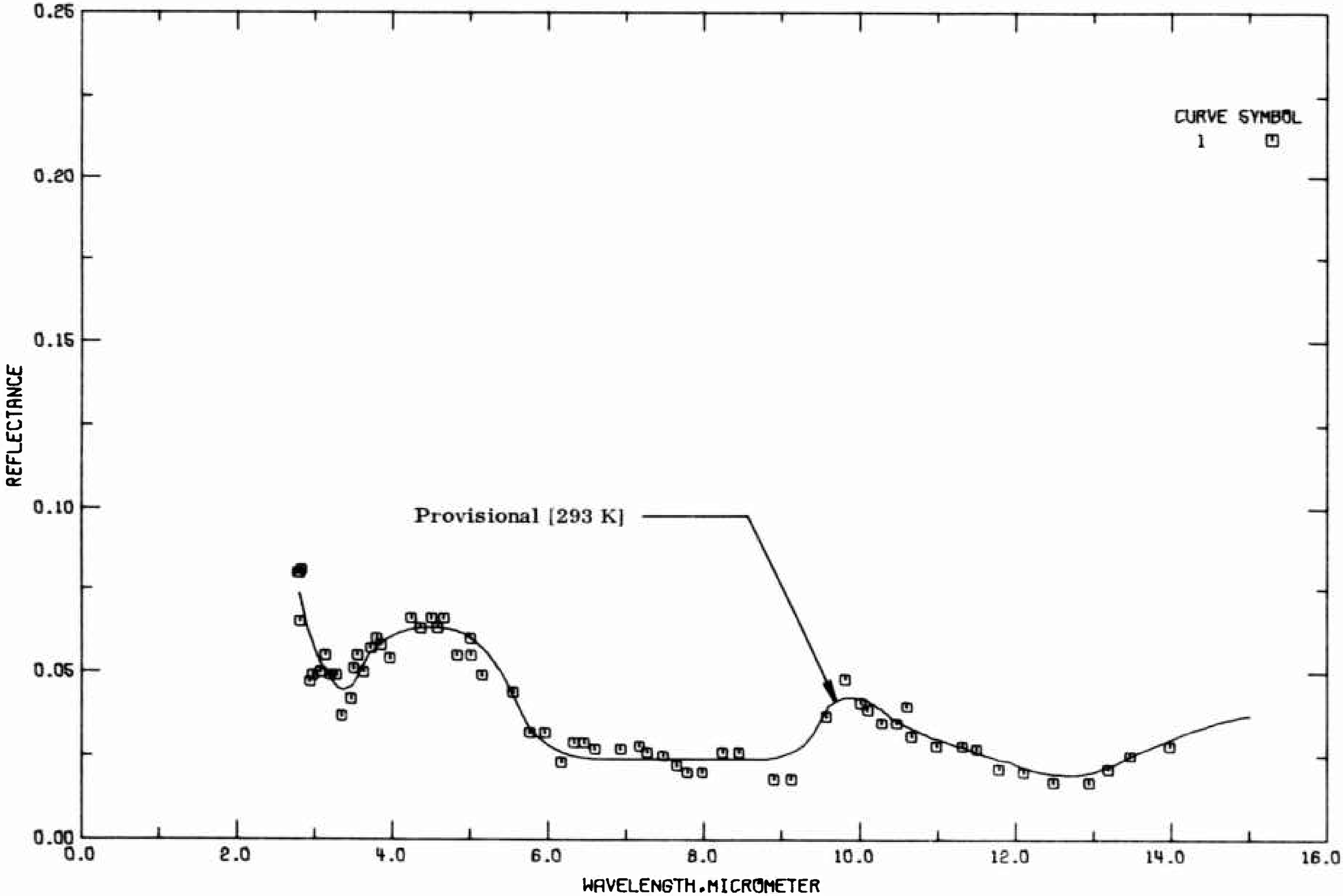


FIGURE 24-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF GLASS FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE).

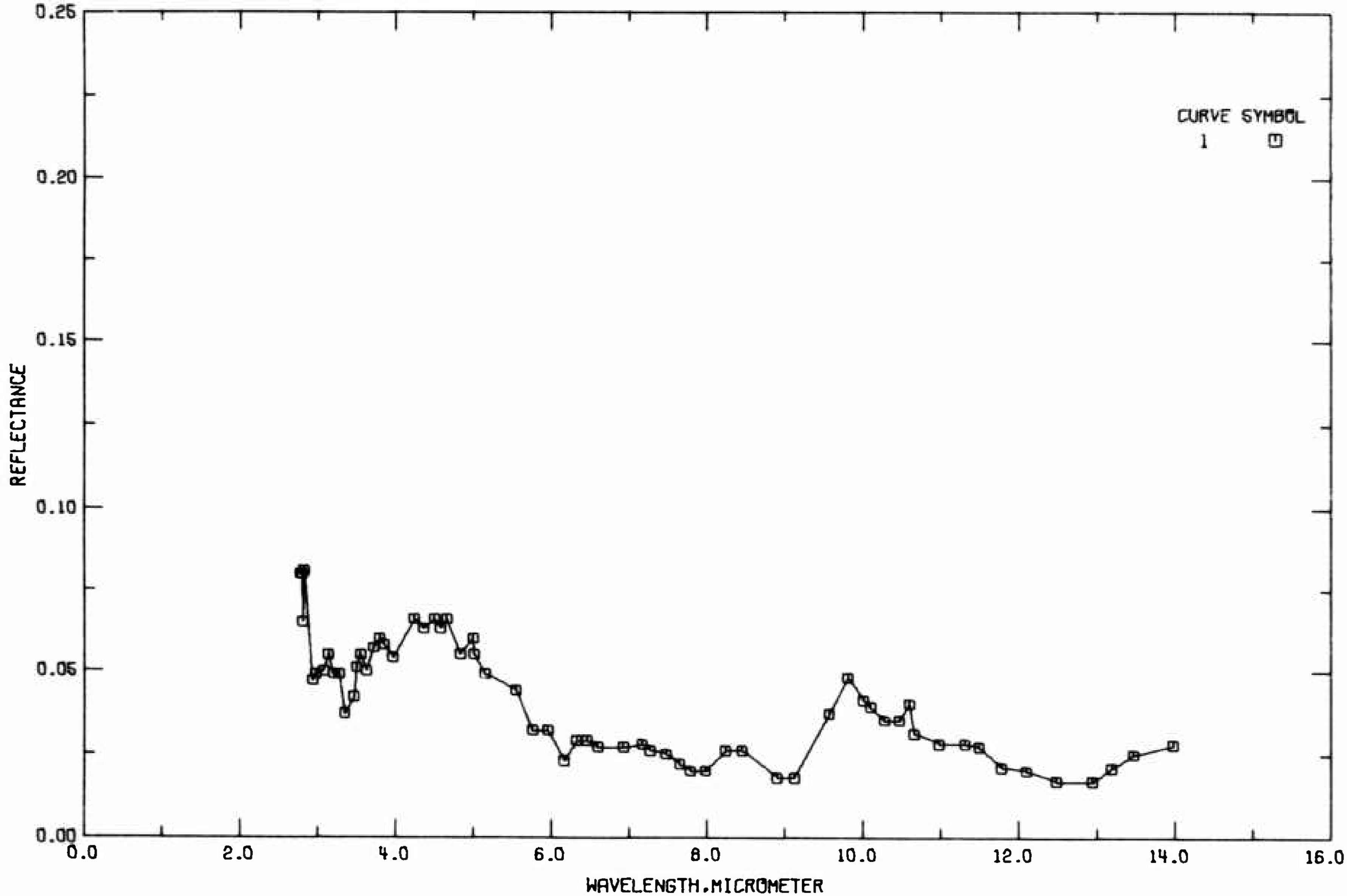


FIGURE 24-4. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF GLASS FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE).

TABLE 24-4. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF GLASS FIBER EPOXY COMPOSITE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00001	Grimm, T.C.	1972	2.0-14.7	293		Bare surface specimen; 2.54 cm square; lightly grit-blasted; prepared by the Organic Chemistry Laboratory in the company where the author worked; measurements made with a Dunn Associates ellipsoidal mirror reflectometer; data extracted from a figure; relative reflectance reported; multiplied by 0.95 to convert to absolute values (gold reference mirror used); $\theta = 15°$, $\omega' = 2\pi$.

TABLE 24-5. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF GLASS FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ
CURVE 1		CURVE	1(CONT.)
T = 293.		6.93	0.027
2.58	0.262	7.17	0.028
2.66	0.196	7.27	0.026
2.70	0.138	7.48	0.025
2.74	0.103	7.65	0.022
2.78	0.080	7.79	0.020
2.80	0.080	7.98	0.020
2.81	0.065	8.24	0.026
2.83	0.081	8.45	0.026
2.94	0.047	8.90	0.018
2.98	0.049	9.12	0.018
3.08	0.050	9.57	0.037
3.14	0.055	9.81	0.048
3.20	0.049	10.01	0.041
3.28	0.049	10.10	0.039
3.35	0.037	10.28	0.035
3.47	0.042	10.47	0.035
3.50	0.051	10.60	0.040
3.55	0.055	10.66	0.031
3.63	0.050	10.98	0.028
3.72	0.057	11.31	0.028
3.80	0.060	11.49	0.027
3.85	0.058	11.78	0.021
3.97	0.054	12.10	0.020
4.24	0.066	12.48	0.017
4.36	0.063	12.94	0.017
4.50	0.066	13.19	0.021
4.58	0.063	13.47	0.025
4.66	0.066	13.98	0.028
4.83	0.055	14.13	0.028
5.00	0.060	14.23	0.032
5.01	0.055	14.64	0.033
5.15	0.049		
5.55	0.044		
5.76	0.032		
5.96	0.032		
6.17	0.023		
6.33	0.029		
6.46	0.029		
6.60	0.027		

d. Normal Spectral Reflectance (Temperature Dependence)

In Table 24-6, the provisional values of the normal spectral reflectance are given with an estimated uncertainty of ±25%. The variation of the property as a function of temperature is demonstrated in Figure 24-5. For a given wavelength, the normal spectral reflectance remains as a constant from room temperature up to the char region of epoxy. The independency of the reflectance of epoxy composite with temperature has been observed experimentally [A00002]. The reported provisional values are believed to be reasonable in most of the real situation.

TABLE 24-6. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF GLASS FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

T	ρ	T	ρ	T	ρ	T	ρ
LIGHTLY GRIT-BLASTED $\lambda = 2.8$		LIGHTLY GRIT-BLASTED $\lambda = 3.8$		LIGHTLY GRIT-BLASTED $\lambda = 5.0$		LIGHTLY GRIT-BLASTED $\lambda = 10.6$	
250.0	0.074	250.0	0.057	250.0	0.060	250.0	0.034
300.0	0.074	300.0	0.057	300.0	0.060	300.0	0.034
350.0	0.074	350.0	0.057	350.0	0.060	350.0	0.034
400.0	0.074	400.0	0.057	400.0	0.060	400.0	0.034
450.0	0.074	450.0	0.057	450.0	0.060	450.0	0.034
500.0	0.074	500.0	0.057	500.0	0.060	500.0	0.034

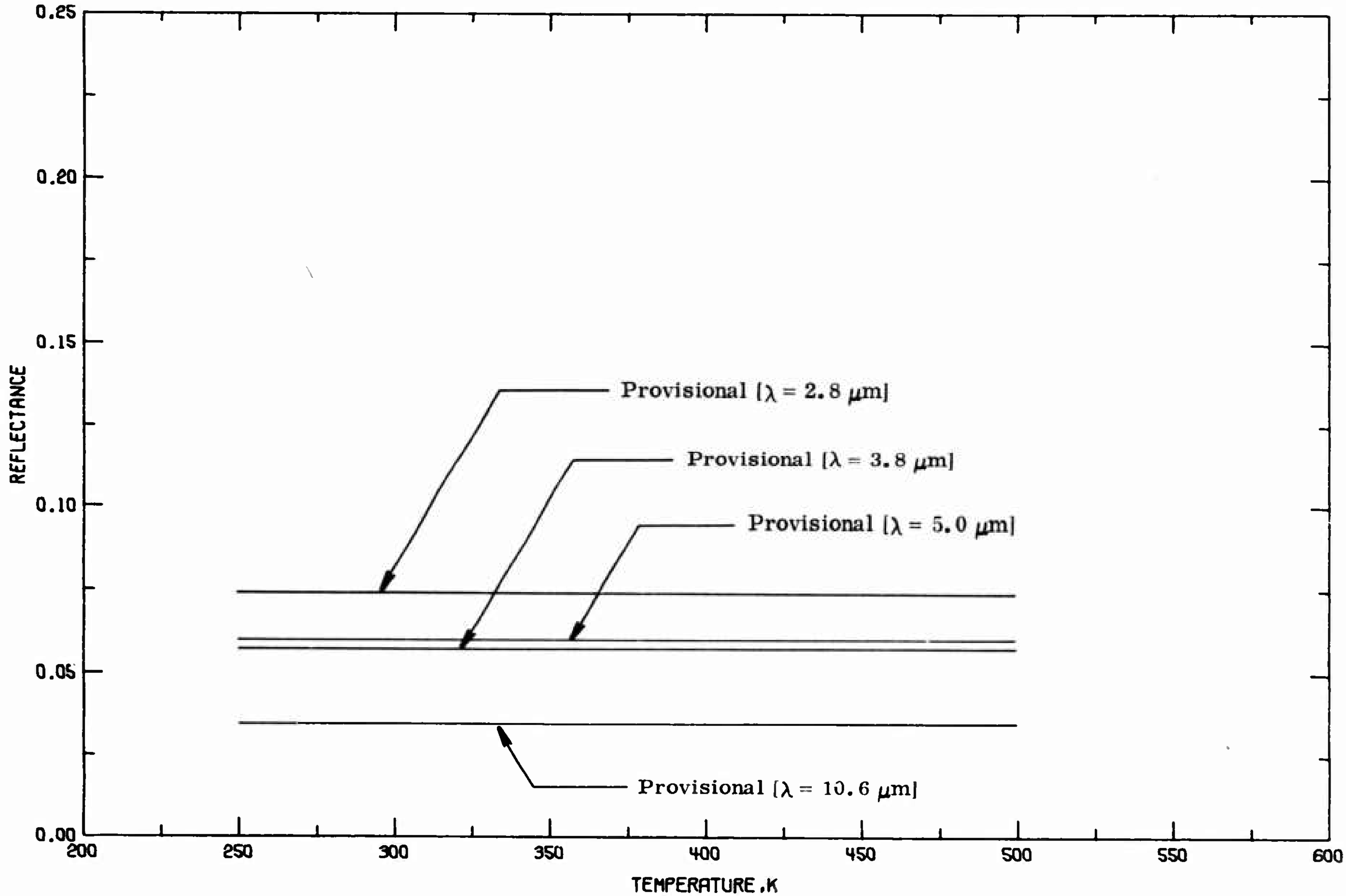


FIGURE 24-5. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF GLASS FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE).

e. Normal Spectral Absorptance (Wavelength Dependence)

The normal spectral absorptance is obtained according to the Kirchhoff's law, i.e., numerically the absorptance is equal to the emittance. As a result, Table 24-7 and Figure 24-6 appear the same as Table 24-1 and Figure 24-1, as well as the estimated uncertainties ($\pm 20\%$).

TABLE 24-7. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF GLASS FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

λ	α
LIGHTLY GRIT-BLASTED T = 293	
2.8	0.926
3.0	0.943
3.5	0.954
3.8	0.943
4.0	0.939
4.5	0.937
5.0	0.940
5.5	0.954
6.0	0.971
6.5	0.976
7.0	0.976
7.5	0.976
8.0	0.976
8.5	0.976
9.0	0.975
9.5	0.964
10.0	0.957
10.5	0.964
10.6	0.966
11.0	0.979
11.5	0.974
12.0	0.977
12.5	0.980
13.0	0.980
13.5	0.975
14.0	0.970
14.5	0.966
15.0	0.963

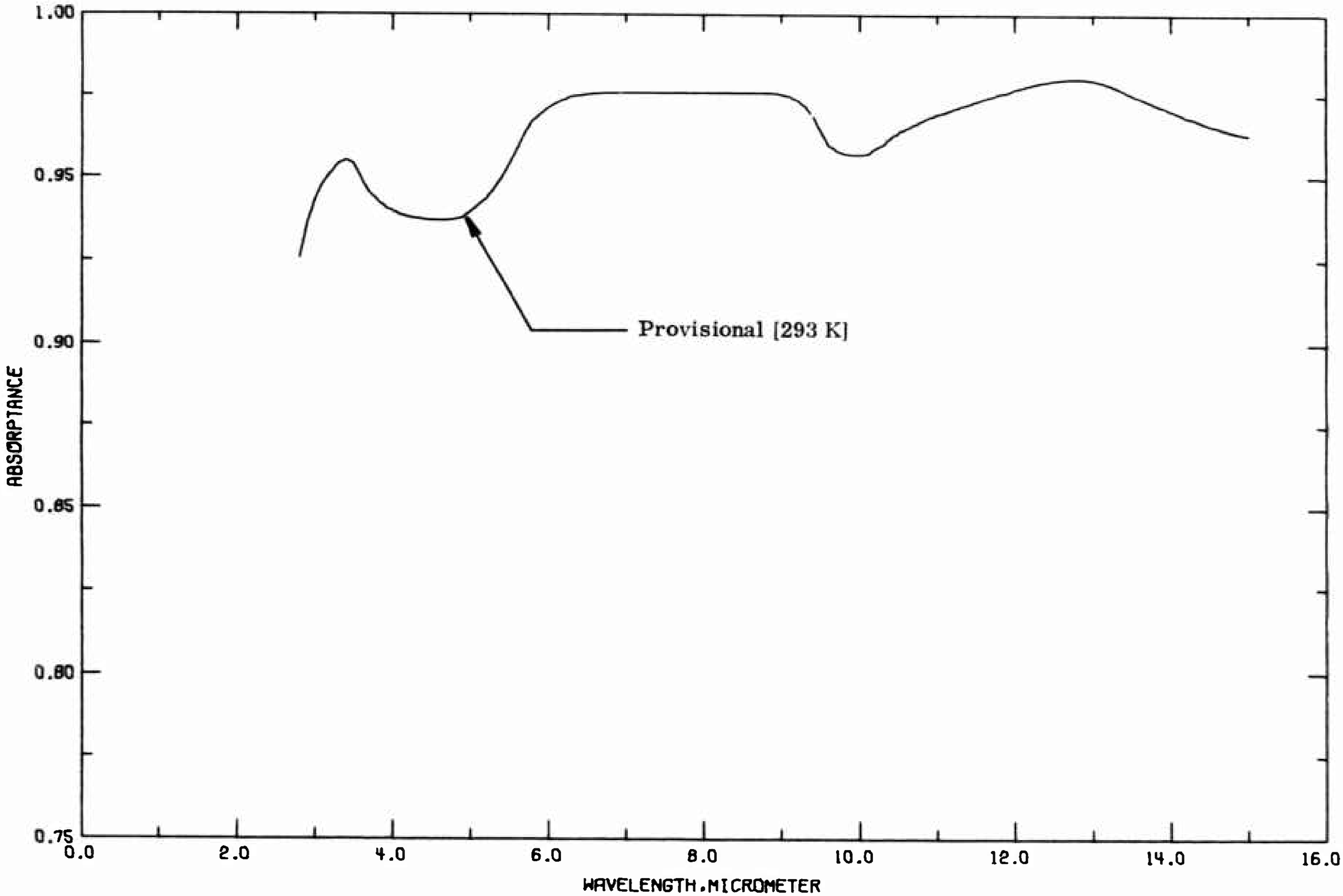


FIGURE 24-6. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF GLASS FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE).

f. Normal Spectral Absorptance (Temperature Dependence)

The normal spectral absorptance as a function of temperature is given in Table 24-8 and plotted in Figure 24-7. The generated values are considered as provisional with 20% uncertainty. Here, we present the property values as constant for a given wavelength because it has been observed in epoxy composites that the radiative properties do not change appreciably with temperature [A00002]. With 20% uncertainty, the provisional values can be safely used for most of the true surfaces.

TABLE 24-8. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF GLASS FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

T	α	T	α	T	α	T	α
LIGHTLY GRIT-BLASTED λ = 2.8		LIGHTLY GRIT-BLASTED λ = 3.8		LIGHTLY GRIT-BLASTED λ = 5.0		LIGHTLY GRIT-BLASTED λ = 10.6	
250.0	0.926	250.0	0.943	250.0	0.940	250.0	0.966
300.0	0.926	300.0	0.943	300.0	0.940	300.0	0.966
350.0	0.926	350.0	0.943	350.0	0.940	350.0	0.966
400.0	0.926	400.0	0.943	400.0	0.940	400.0	0.966
450.0	0.926	450.0	0.943	450.0	0.940	450.0	0.966
500.0	0.926	500.0	0.943	500.0	0.940	500.0	0.966

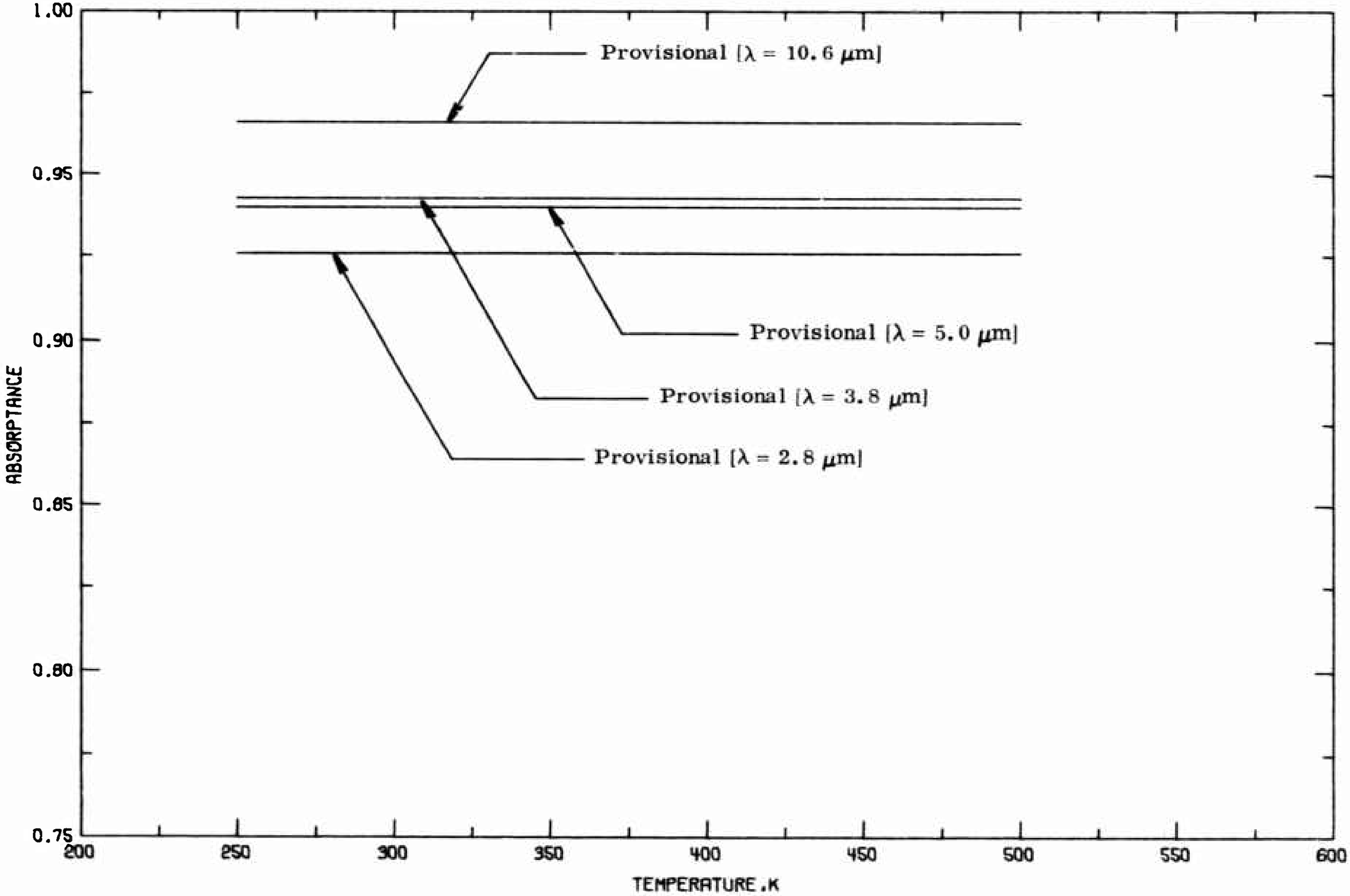


FIGURE 24-7. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF GLASS FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE).

4.25. Graphite Fiber Epoxy Composite

Composite materials have received great interest in the last decade because they provide unusual combinations of properties which cannot be obtained with any single, homogeneous substance. In aircraft and missile design, they have provided structural materials of very high strength and elastic modulus which also have low densities.

The graphite fibers used in composites are made by the carbonization of organic filaments. The filaments most often used today are made from polyacrylonitrile (PAN) although rayon and acrylic fibers have been used to a limited extent. The mechanical properties of graphite fiber depend on the temperatures used in the carbonization process. Temperatures of 2800-3300 K result in fibers with high elastic modulus but relatively low tensile strength. Temperatures of 1800-2300 K yield fibers of the greatest tensile strength but only moderate modulus of elasticity. The density of the fibers varies from 1.74-1.94 g cm^{-3} depending on the carbonization temperatures used. The filaments are normally produced in untwisted, loose bundles, or tows, consisting of ten thousand fibers.

Modified epoxy resins developed specifically for use in composites with graphite fiber are available commercially. These are thermosetting resins used for low pressure laminating which normally cannot be used in continuous service above about 450 K although intermittent service at temperature up to 490 K is possible. Many of the various epoxy resins used as matrix constituents of composites are proprietory formulations whose exact chemical compositions are not available.

For aerospace design, graphite fiber-epoxy composites are generally supplied by the manufacturer as prepregs. These are tapes or broadgoods consisting of the graphite fibers impregnated with the epoxy resin matrix which have been only partially cured and consequently have a limited shelf life and require special storage facilities. The prepregs are used in the fabrication of laminates whose layer orientations are tailored to match individual design requirements. Consequently, large numbers of individually different crossplied laminates are likely to be encountered, each of which has distinctive properties and characteristics, and hence must be distinctly identified whenever it is to be associated with specific quantitative data.

The graphite fiber epoxy is fabricated primarily for aircraft constructions because of its advantages. Much of its mechanical and thermal properties are studied. As a result, sizable amount of data are made available at users disposal.

With regard to the thermal radiative properties of the composite, it is unfortunate to find that there is only one set of experimental data on the normal spectral reflectance

uncovered by our search. This leaves us no choice but to use it as the basis in the estimation of the most probable values of the radiative properties for graphite fiber epoxy composite.

The fact that the composite material is made by bonding graphite fibers in a matrix of epoxy resin implies that epoxy is the material which predominately contributes to the thermal radiative properties of the composite material. The other component, the graphite fiber, plays a minor role. Indeed, by comparing the shapes of the normal spectral reflectance curves (Figure 25-4 in this subsection and Figures 23-4 and 24-4 in subsections 4.23 and 4.24 respectively) we can see the spectral band patterns of the three epoxy composite materials (boron fiber epoxy composite, glass fiber epoxy composite and graphite fiber epoxy composite) are similar.

Reflectance of epoxy is generally fairly low, about 10%, for wavelengths longer than 2.5 μm. Also, it does not change appreciably as the material is heated up and goes decomposition phase and into the char region [A00004]. In other words, the radiative properties of epoxy are independent of temperature.

For epoxy composite materials, the following two relations are commonly used as good approximations:

$$\alpha(0,\lambda) = 1 - \rho(0,2\pi,\lambda);$$

$$\epsilon(0,\lambda) = \alpha(0,\lambda),$$

because of opaqueness of the materials.

According to the facts discussed above, we are in a position to make reasonable estimation of the following six subproperties for graphite fiber epoxy composite based on the single available set of reflectance data:

Normal spectral emittance (wavelength dependence)
Normal spectral emittance (temperature dependence)
Normal spectral reflectance (wavelength dependence)
Normal spectral reflectance (temperature dependence)
Normal spectral absorptance (wavelength dependence)
Normal spectral absorptance (temperature dependence)

a. Normal Spectral Emittance (Wavelength Dependence)

Provisional values of the thermal spectral emittance of slightly grit-blasted boron fiber epoxy composite are obtained from the analyzed result of reflectance by using

the relation $\alpha(0,\lambda) = 1 - \rho(0, 2\pi, \lambda)$ and Kirchhoff's law. Such conversion is frequently used for the materials whose reflectance is known [A00004]. The provisional values, listed in Table 25-1 and plotted in Figure 25-1, are in general very close to unity. For rough uses, a value of 0.95 can be safely used because the uncertainty of the provisional values is ±20%.

TABLE 25-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ε]

λ	ε
LIGHTLY GRIT-BLASTED T = 293	
2.5	0.903
2.8	0.921
3.0	0.927
3.5	0.928
3.8	0.900
4.0	0.894
4.5	0.888
5.0	0.888
5.5	0.893
6.0	0.914
6.5	0.938
7.0	0.945
7.5	0.947
8.0	0.947
8.5	0.946
9.0	0.944
9.5	0.939
10.0	0.931
10.5	0.926
10.6	0.925
11.0	0.925
11.5	0.930
12.0	0.937
12.5	0.935
13.0	0.928
13.5	0.914
14.0	0.904
14.5	0.898
15.0	0.894

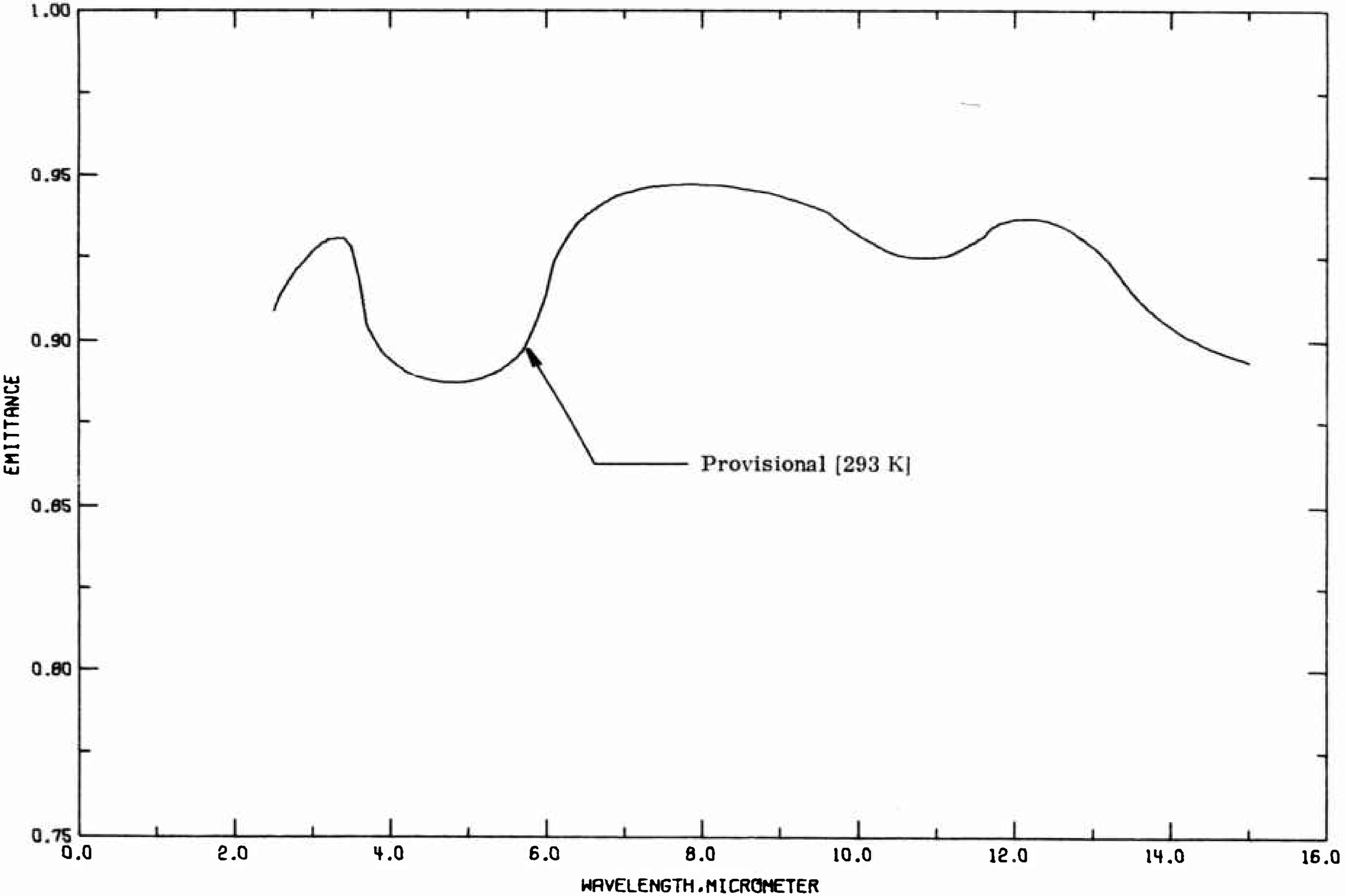


FIGURE 25-1. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE).

b. Normal Spectral Emittance (Temperature Dependence)

The normal spectral emittance as a function of temperature is given in Table 25-2 and plotted in Figure 25-2. The generated values are considered as provisional with 20% uncertainty. Here, we present the property values as a constant for a given wavelength because it has been observed in epoxy composites that the radiative properties do not change appreciably with temperature [A00002]. With 20% uncertainty, the provisional values can be safely used for most of the true surfaces.

TABLE 25-2. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF GRAPHITE FIBER/EPOXY COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; EMITTANCE, ϵ]

T	ϵ	T	ϵ	T	ϵ	T	ϵ
LIGHTLY GRIT-BLASTED λ = 2.8		LIGHTLY GRIT-BLASTED λ = 3.8		LIGHTLY GRIT-BLASTED λ = 5.0		LIGHTLY GRIT-BLASTED λ = 10.6	
250.0	0.921	250.0	0.900	250.0	0.888	250.0	0.925
300.0	0.921	300.0	0.900	300.0	0.888	300.0	0.925
350.0	0.921	350.0	0.900	350.0	0.888	350.0	0.925
400.0	0.921	400.0	0.900	400.0	0.888	400.0	0.925
450.0	0.921	450.0	0.900	450.0	0.888	450.0	0.925
500.0	0.921	500.0	0.900	500.0	0.888	500.0	0.925

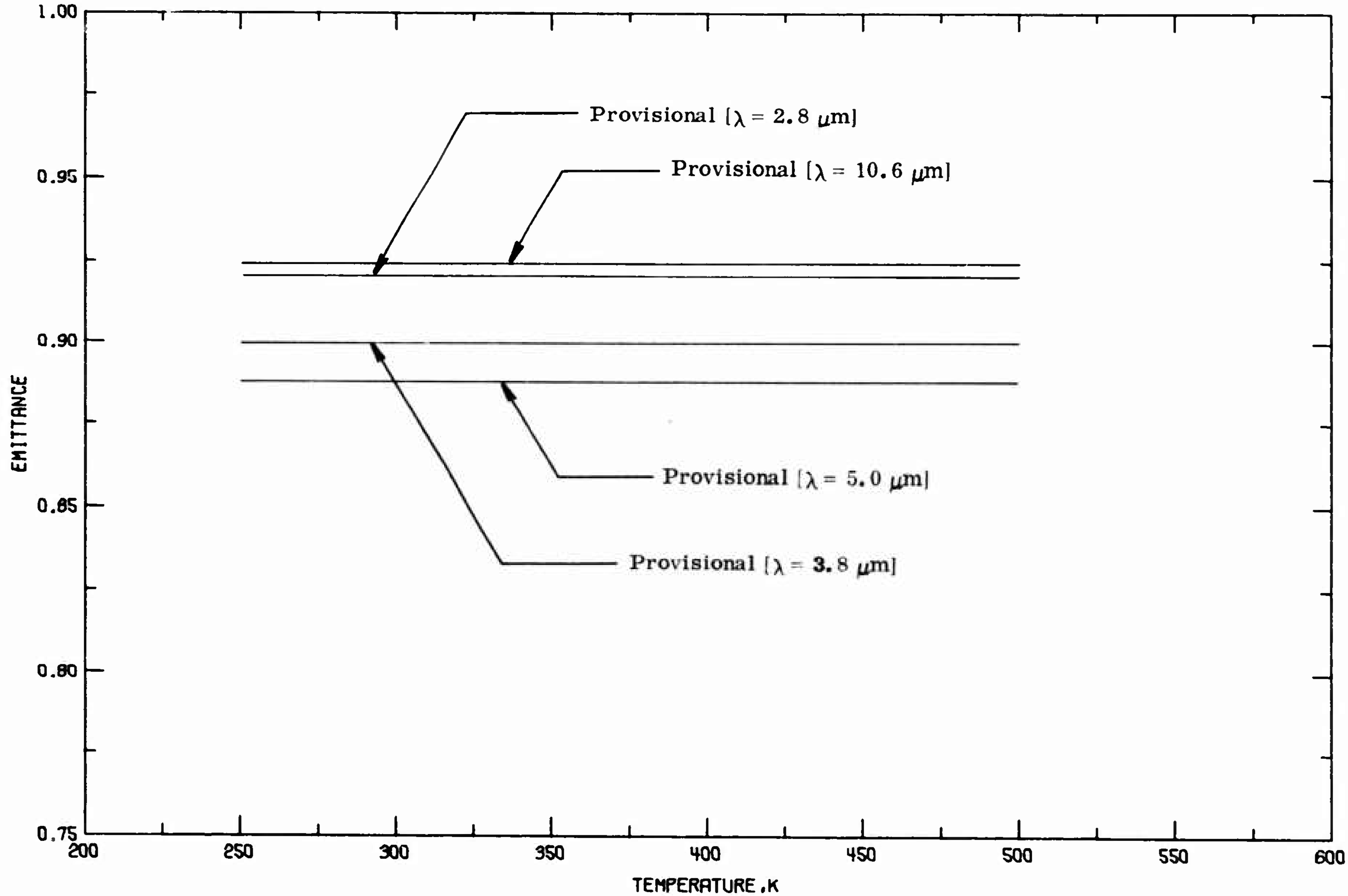


FIGURE 25-2. PROVISIONAL NORMAL SPECTRAL EMITTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE).

c. Normal Spectral Reflectance (Wavelength Dependence)

As given in Table 25-3 and plotted in Figure 25-3, the provisional values of graphite fiber epoxy composite are obtained by reading off from a curve smoothed out from the only available set of data shown in Figure 25-4. It shows a quite complex spectral distribution of energy reflected from the composite material. Because of scantiness of the available data and spectral complexity, no attempt was made to carry out analytical calculations but the smoothing technique. An estimated uncertainty of 25% is given to the provisional values which are believed to be reasonable for most of the real surfaces.

TABLE 25-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

λ	ρ
LIGHTLY GRIT-BLASTED T = 293	
2.5	0.091
2.8	0.079
3.0	0.073
3.5	0.072
3.8	0.100
4.0	0.106
4.5	0.112
5.0	0.112
5.5	0.107
6.0	0.086
6.5	0.062
7.0	0.055
7.5	0.053
8.0	0.053
8.5	0.054
9.0	0.056
9.5	0.061
10.0	0.069
10.5	0.074
10.6	0.075
11.0	0.075
11.5	0.070
12.0	0.063
12.5	0.065
13.0	0.072
13.5	0.086
14.0	0.096
14.5	0.102
15.0	0.106

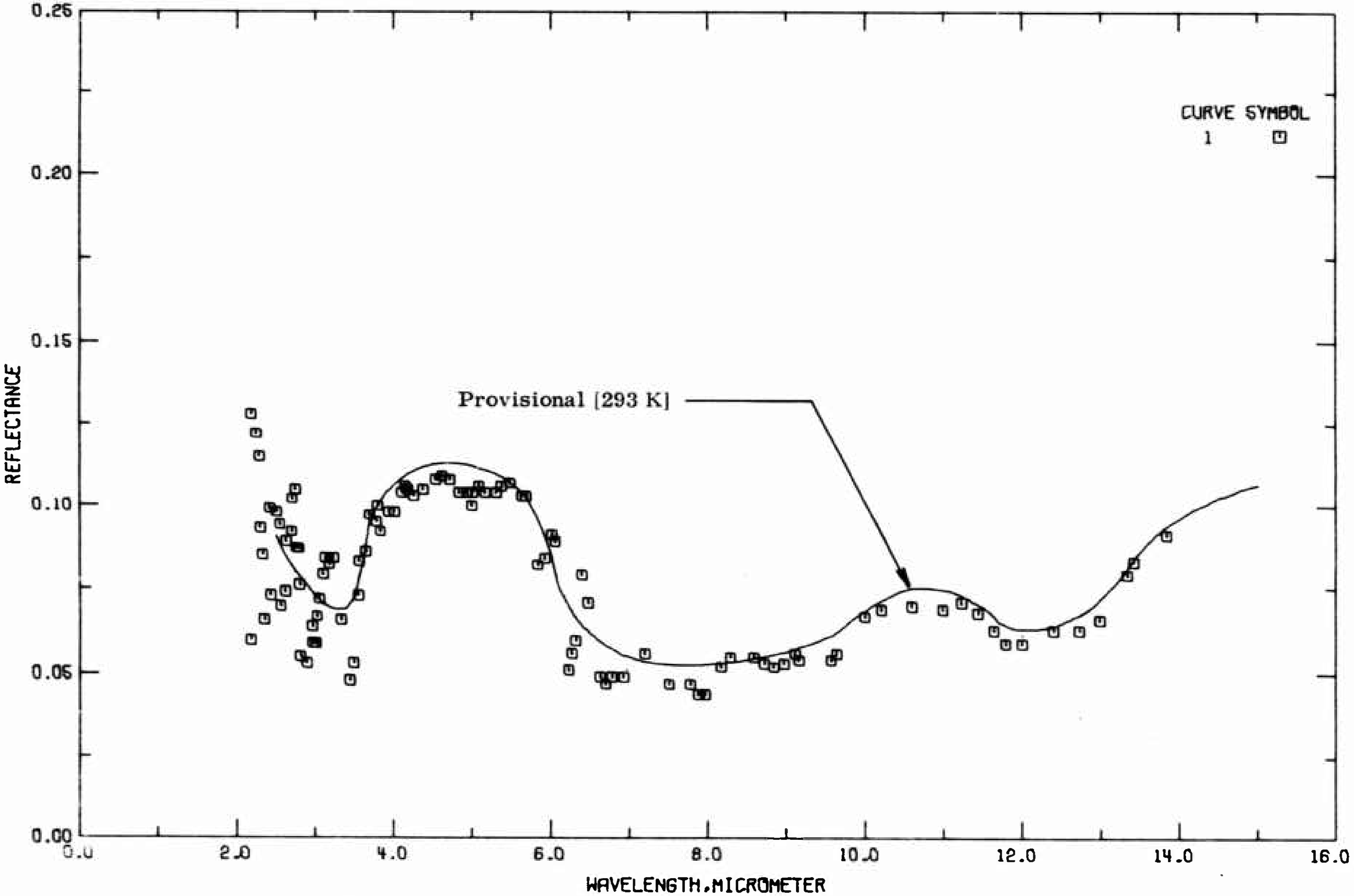


FIGURE 25-3. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE).

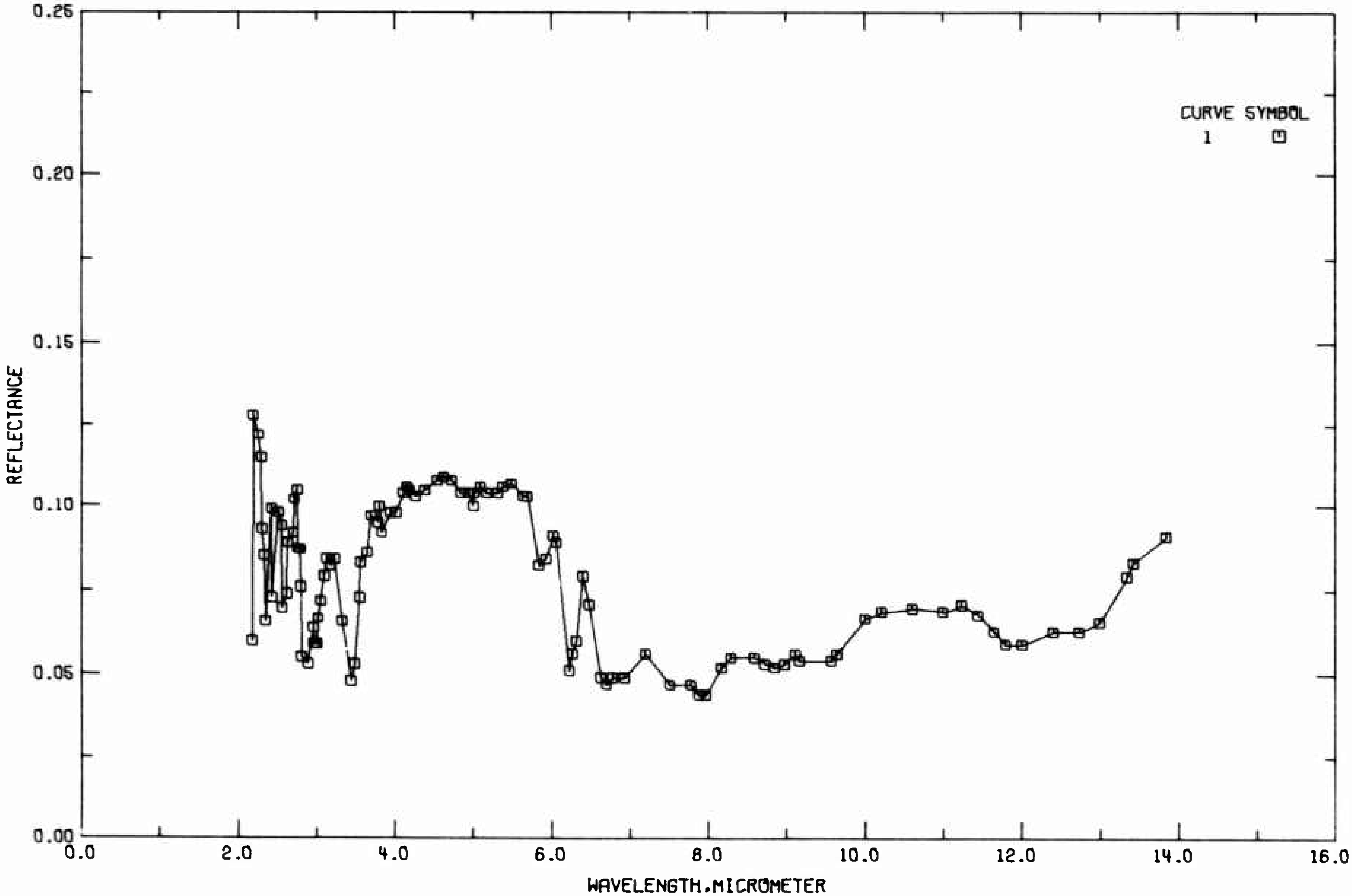


FIGURE 25-4. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE).

TABLE 25-4. MEASUREMENT INFORMATION ON THE NORMAL SPECTRAL REFLECTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (Wavelength Dependence)

Cur. No.	Ref. No.	Author(s)	Year	Wavelength Range, μm	Temperature Range, K	Name and Specimen Designation	Composition (weight percent), Specifications, and Remarks
1	A00001	Grimm, T.C.	1972	2.0-14.7	293		Bare surface specimen; 2.54 cm square; lightly grit-blasted; prepared by the Organic Chemistry Laboratory in the company where the author worked; measurements made with a Dunn Associates ellipsoidal mirror reflectometer; data extracted from a figure; relative reflectance reported; multiplied by 0.95 to convert to absolute values (gold reference mirror used); $\theta = 15°$, $\omega' = 2\pi$.

TABLE 25-5. EXPERIMENTAL NORMAL SPECTRAL REFLECTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ]

λ	ρ	λ	ρ	λ	ρ
CURVE 1		CURVE 1 (CONT.)		CURVE 1 (CONT.)	
T = 295.		3.80	0.100	7.97	0.044
2.18	0.069	3.83	0.092	8.17	0.052
2.19	0.128	3.94	0.098	8.29	0.055
2.25	0.122	4.01	0.098	8.53	0.055
2.29	0.115	4.11	0.104	8.72	0.053
2.30	0.093	4.15	0.106	8.84	0.052
2.33	0.085	4.18	0.105	8.97	0.053
2.35	0.365	4.26	0.103	9.11	0.056
2.42	0.099	4.38	0.105	9.16	0.054
2.43	0.073	4.54	0.108	9.57	0.054
2.51	0.098	4.62	0.109	9.64	0.056
2.55	0.094	4.72	0.108	10.00	0.067
2.56	0.070	4.84	0.104	10.21	0.069
2.62	0.074	4.94	0.104	10.60	0.070
2.63	0.089	5.00	0.100	10.99	0.069
2.70	0.092	5.01	0.104	11.23	0.071
2.71	0.102	5.09	0.106	11.44	0.068
2.75	0.105	5.17	0.104	11.64	0.063
2.76	0.087	5.31	0.104	11.79	0.059
2.79	0.087	5.38	0.106	12.00	0.059
2.80	0.076	5.49	0.107	12.40	0.063
2.81	0.055	5.64	0.103	12.73	0.063
2.89	0.053	5.69	0.103	12.99	0.066
2.96	0.064	5.84	0.082	13.34	0.079
2.97	0.059	5.93	0.084	13.42	0.083
3.01	0.059	6.02	0.091	13.84	0.091
3.02	0.067	6.06	0.089	14.18	0.091
3.05	0.072	6.23	0.051	14.44	0.095
3.10	0.079	6.27	0.056	14.69	0.100
3.13	0.084	6.32	0.060		
3.18	0.082	6.40	0.079		
3.23	0.084	6.48	0.071		
3.33	0.066	6.63	0.049		
3.44	0.048	6.70	0.047		
3.49	0.053	6.78	0.049		
3.55	0.073	6.93	0.049		
3.56	0.083	7.20	0.056		
3.65	0.086	7.51	0.047		
3.69	0.097	7.78	0.047		
3.78	0.095	7.88	0.044		

d. Normal Spectral Reflectance (Temperature Dependence)

In Table 25-6, the provisional values of the normal spectral reflectance are given with an estimated uncertainty of $\pm 25\%$. The variation of the property as a function of temperature is demonstrated in Figure 25-5. For a given wavelength, the normal spectral reflectance remains as a constant from room temperature up to the char region of epoxy. The independency of the reflectance of epoxy composite with temperature has been observed experimentally [A00002]. The reported provisional values are believed to be reasonable in most of the real situation.

TABLE 25-6. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; REFLECTANCE, ρ)

LIGHTLY GRIT-BLASTED λ = 2.8		LIGHTLY GRIT-BLASTED λ = 3.8		LIGHTLY GRIT-BLASTED λ = 5.0		LIGHTLY GRIT-BLASTED λ = 10.6	
250.0	0.079	250.0	0.100	250.0	0.112	250.0	0.075
300.0	0.079	300.0	0.100	300.0	0.112	300.0	0.075
350.0	0.079	350.0	0.100	350.0	0.112	350.0	0.075
400.0	0.079	400.0	0.100	400.0	0.112	400.0	0.075
450.0	0.079	450.0	0.100	450.0	0.112	450.0	0.075
500.0	0.079	500.0	0.100	500.0	0.112	500.0	0.075

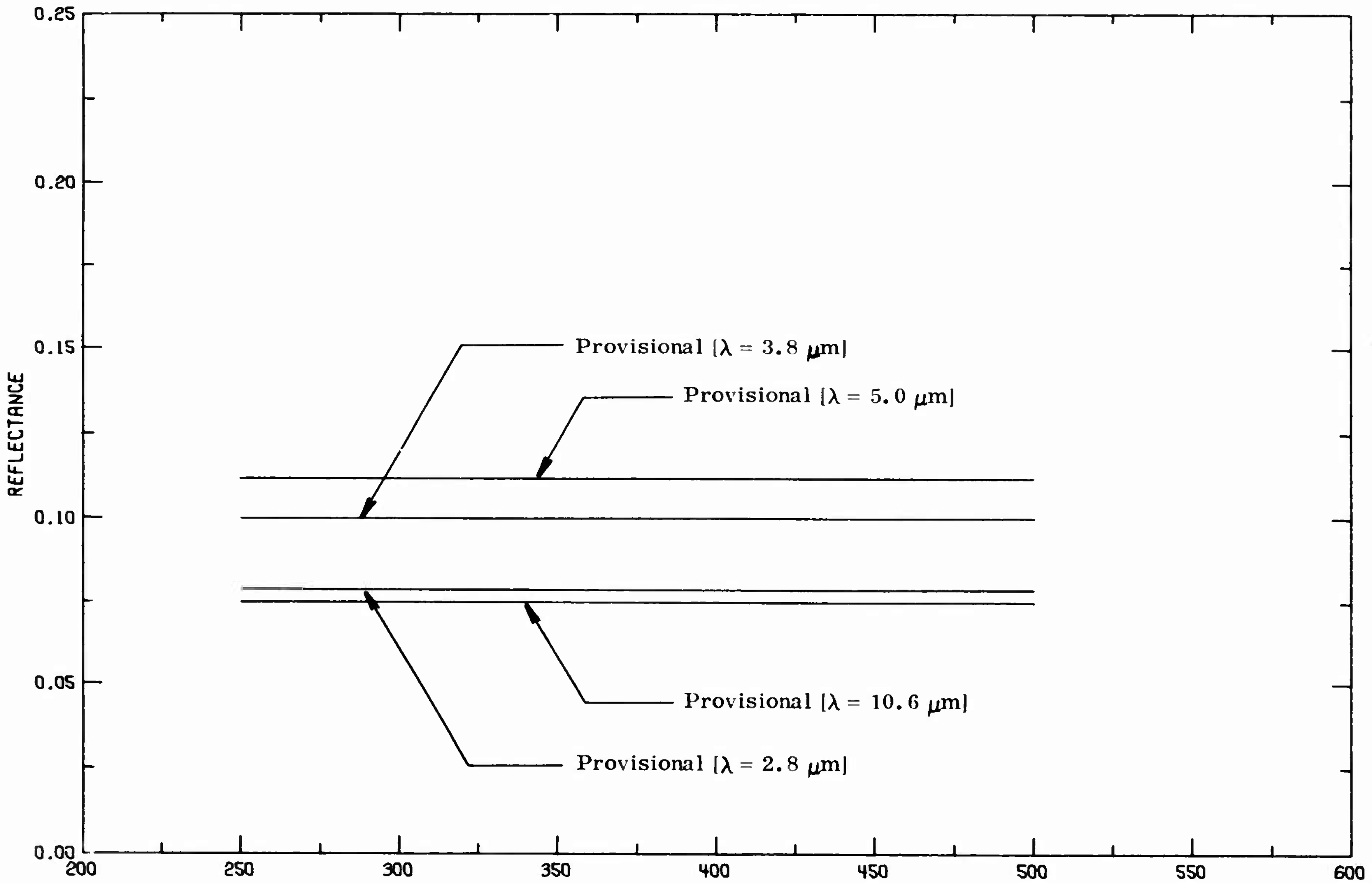


FIGURE 25-5. PROVISIONAL NORMAL SPECTRAL REFLECTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE).

e. Normal Spectral Absorptance (Wavelength Dependence)

The normal spectral absorptance is obtained according to the Kirchhoff's law, i.e., numerically the absorptance is equal to the emittance. As a result, Table 25-7 and Figure 25-6 appear the same as Table 25-1 and Figure 25-1, as well as the estimated uncertainties ($\pm 20\%$).

TABLE 25-7. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE)

(WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α)

λ	α
LIGHTLY GRIT-BLASTED T = 293	
2.5	0.909
2.8	0.921
3.0	0.927
3.5	0.928
3.8	0.900
4.0	0.894
4.5	0.889
5.0	0.888
5.5	0.893
6.0	0.914
6.5	0.938
7.0	0.945
7.5	0.947
8.0	0.947
8.5	0.946
9.0	0.944
9.5	0.939
10.0	0.931
10.5	0.926
10.6	0.925
11.0	0.925
11.5	0.930
12.0	0.937
12.5	0.935
13.0	0.928
13.5	0.914
14.0	0.904
14.5	0.895
15.0	0.894

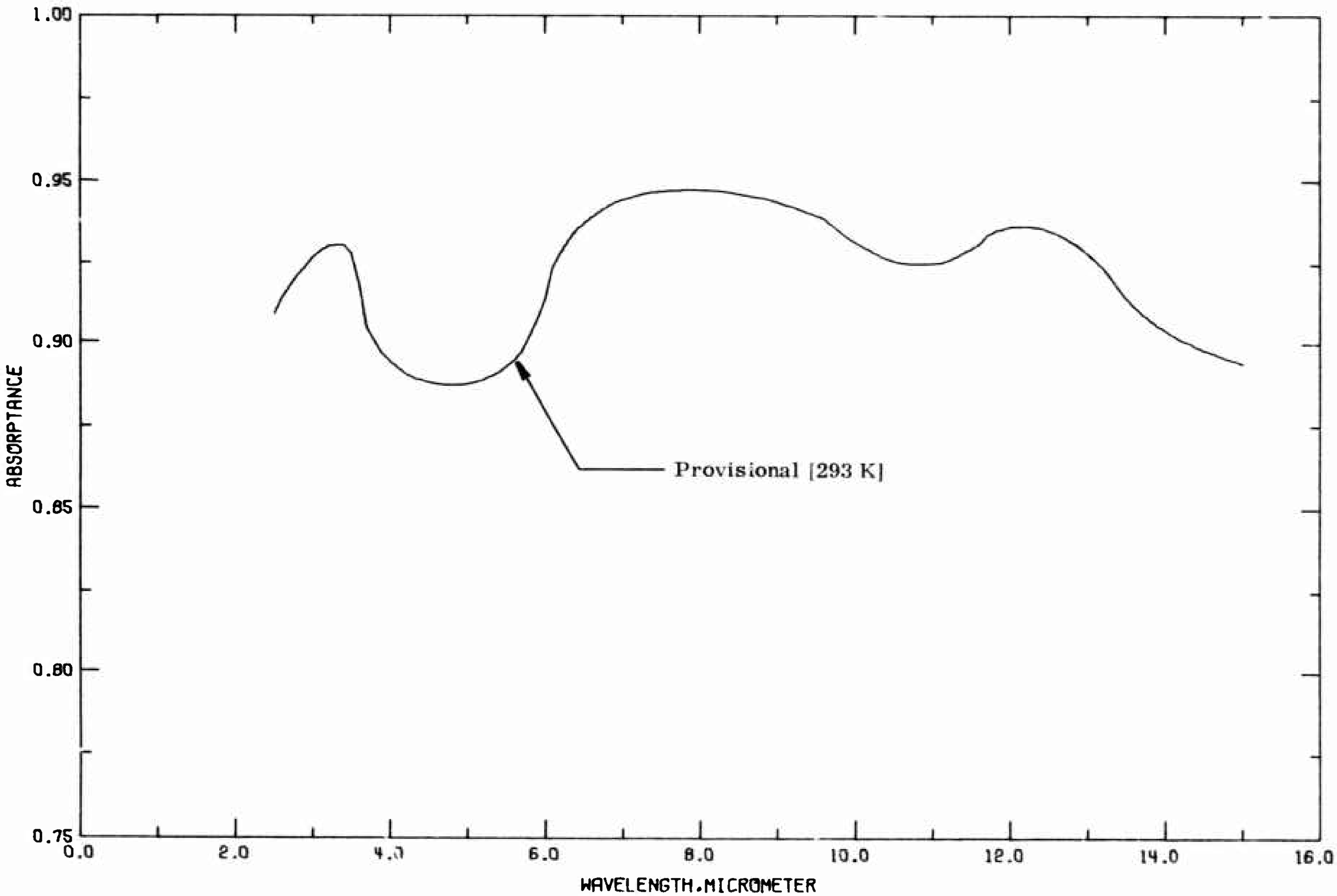


FIGURE 25-6. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (WAVELENGTH DEPENDENCE).

f. Normal Spectral Absorptance (Temperature Dependence)

The normal spectral absorptance as a function of temperature is given in Table 25-8 and plotted in Figure 25-7. The generated values are considered as provisional with 20% uncertainty. Here, we present the property values as constant for a given wavelength because it has been observed in epoxy composites that the radiative properties do not change appreciably with temperature [A00002]. With 20% uncertainty, the provisional values can be safely used for most of the true surfaces.

TABLE 25-8. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE)

[WAVELENGTH, λ, μm; TEMPERATURE, T, K; ABSORPTANCE, α]

T	α	T	α	T	α	T	α
LIGHTLY GRIT-BLASTED λ = 2.8		LIGHTLY GRIT-BLASTED λ = 3.8		LIGHTLY GRIT-BLASTED λ = 5.0		LIGHTLY GRIT-BLASTED λ = 10.6	
250.0	0.921	250.0	0.900	250.0	0.888	250.0	0.925
300.0	0.921	300.0	0.900	300.0	0.888	300.0	0.925
350.0	0.921	350.0	0.900	350.0	0.888	350.0	0.925
400.0	0.921	400.0	0.900	400.0	0.888	400.0	0.925
450.0	0.921	450.0	0.900	450.0	0.888	450.0	0.925
500.0	0.921	500.0	0.900	500.0	0.888	500.0	0.925

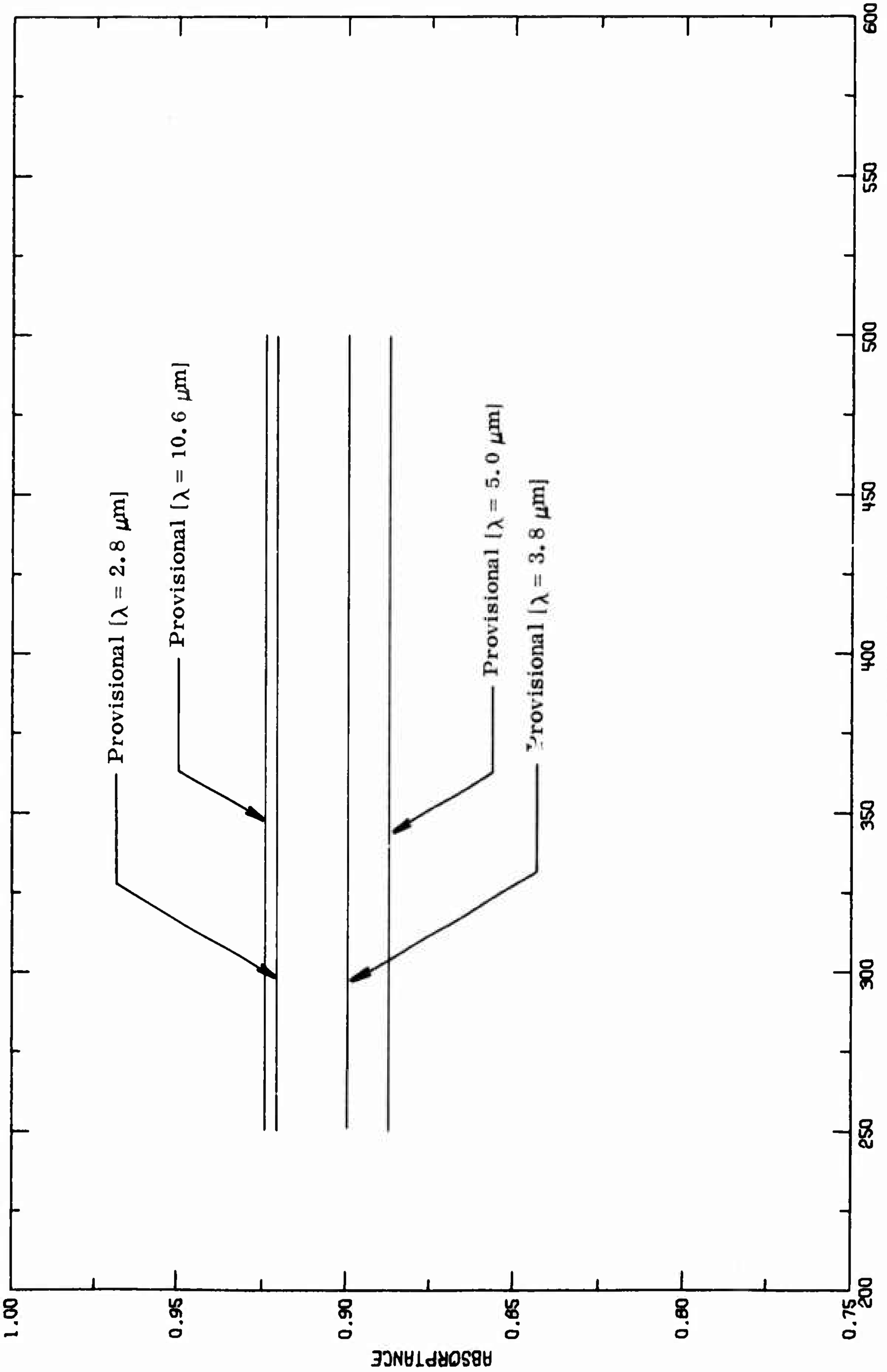


FIGURE 25-7. PROVISIONAL NORMAL SPECTRAL ABSORPTANCE OF GRAPHITE FIBER EPOXY COMPOSITE (TEMPERATURE DEPENDENCE).

4.26. Silicon Nitride with Chopped Graphite Fiber

No information on the thermal radiative properties of this composite material was uncovered from the search of literature. Consequently, no tabulation or recommendation of the thermal radiative properties of this material is possible at this time.

However, it is reasonable to assume that this material in its bulk form is opaque; that is, the transmittance is zero.

4.27. Silicon Nitride with Vitreous Silica

No information on the thermal radiative properties of this composite material was uncovered from the search of literature. Consequently, no tabulation or recommendation of the thermal radiative properties of this material is possible at this time.

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